Changes to the Teaching of Clinical Masking for Audiology Students, Including a New Software-Based Teaching Tool, *maskME*.

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Abstract

Introduction. Hearing tests often require masking, the procedure that isolates the ears so they are able to be tested separately. Known to be a difficult topic to teach and learn, the present study set out to create and evaluate new resources to teach masking, including a custom piece of simulation software, maskME. Simulation software for audiometry, the battery of tests that measure a person's hearing, have been in existence since the 1980s. Studies investigating their potential for use with audiology students have emerged in the past fifteen years, many with promising findings.

Methods. There were four sessions on masking and six groups of participants ranging in size from four to 21 participants. There were 25 non-audiology student participants and 23 audiology student participants. Iterative changes were made to the sessions based on feedback, and the sessions were either two or three hours long. All participants completed a quiz and questionnaire after attending a session and the audiology students also completed a pre-session quiz. Quiz scores were compared within and between groups. Questionnaire responses were used to evaluate how useful participants rated aspects of the session.

Results. This study found that declarative knowledge of masking concepts increased for audiology students after attending a one-off session in which maskME simulation software was used as a teaching resource. It also exposed the limits of what could be taught to non-audiology student participants in a one-off session. Responses to a questionnaire about the usefulness of the session were generally positive, with mean scores between *agree* and *strongly agree* in each of the four sessions.

Conclusion. This study added to the growing body of literature that supports the use of simulation software in audiology education.

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Abbreviations

AC – air conduction

BC – bone conduction

ABG – air-bone gap

TE – test ear

NTE – non-test ear

PL – presentation level

CBS – computer-based simulator

CAS – Clinical Audiometry Simulator

IA – interaural attenuation

OE – occlusion effect

UC – University of Canterbury

WRS – Word Recognition Score test

DNA – did not answer

1 Introduction

1.1 Introduction to audiology

Hearing tests measure a person's hearing sensitivity and are most commonly done by audiologists, audiometrists, and those trained to do hearing screening for pre-school children.

Audiology as a field surged after World War II in the United States to aid veterans who had suffered damage to their hearing during the war (Katz, 2015). Audiologists and audiometrists are allied health professionals who work in both public and private sectors. As of December 2018, there were 435 audiologists and 43 audiometrists in New Zealand, with approximately 30 graduating students entering the workforce every year (A. Mercer, personal communication, November 30, 2018). Audiology is offered at the University of Canterbury and the University of Auckland and is a two-year, full-time master's course. A Diploma of Audiometry can be gained online through an Australian education provider. The profession of audiology is concerned with supporting those with hearing loss and vestibular abnormalities in their daily lives.

Hearing loss can impact a person's ability to communicate, which can then have considerable repercussions for their social and work life, as well as education (Lawson & Peterson, 2011). Once identified by a hearing test, hearing loss can be managed in a variety of ways, including hearing aids, listening devices, cochlear implants, communicating using sign language, and/or communication strategies.

Information in the following two sections has come from Gelfand (2016). There are two types of peripheral hearing loss: sensorineural, where the damage is either in the inner ear or in the auditory nerve, or conductive, where the problem is either in the middle ear or outer ear. A person can have both types of hearing loss, in which case the loss is described as mixed. Sensorineural hearing loss is permanent whereas conductive hearing losses can be permanent or temporary, sometimes improved with surgery.

Two key elements of standard hearing tests are pure-tone audiometry and speech audiometry. Pure-tone testing involves playing a variety of beeps and asking the person to indicate when they hear it, usually by pressing a button. This identifies the quietest sound a person can hear (their *behavioural threshold)* at that particular frequency. The frequencies tested are 250 Hz to 8000 Hz, which are the most important for understanding speech. Pure-tone sensitivity is tested through two pathways: air conduction and bone conduction. Air conduction (AC) thresholds measure how well a person can hear a sound which has travelled through the outer, middle, and into the inner ear. This sound is delivered via insert earphones, supra-aural headphones or free-field speakers. Bone conduction (BC) thresholds are measured with a bone conduction vibrator, placed on the mastoid bone behind the ear or on the forehead. Because the bone conduction pathway bypasses the outer and middle ear, this measures how well a person can detect sound in the inner ear alone, revealing their permanent and underlying hearing sensitivity. Comparing AC and BC thresholds identifies different types of hearing losses and can determine site of lesion.

The most common form of speech audiometry used in New Zealand involves playing lists of ten short words at varying levels and asking the person to repeat back what was heard. These words are the meaningful consonant-vowel-consonant word lists created by Boothroyd (1968). For both pure-tone audiometry and speech audiometry, it is essential to get separate ear information, and the way to ensure this is to perform clinical masking (Gelfand, 2016).

1.2 Clinical masking

Clinical masking is the procedure used to isolate the test ear by presenting narrowband noise into the ear not being tested (the “non-test ear”). If hearing thresholds between the ears are significantly different, sound presented in the test ear can inadvertently be heard in the non-test ear. The term *masking* will be used throughout this thesis instead of *clinical masking.* Masking raises (worsens) the threshold of the non-test ear and eliminates its ability to detect the test signal before the test ear does. During a hearing test, if the tester suspects that the non-test ear is the ear detecting the signal intended for the test ear, “cross-hearing” could be happening and masking is required (Gelfand, 2016).

In 1952, Denes and Naunton wrote that the need for masking to ensure true separate ear information had been known for a long time; masking is not a new or novel concept in audiometry. Narrowband noise, a type of noise centred upon the frequency of the test signal, is exclusively used for masking pure-tones (Gunnar Lidén et al., 1959). Broadband noise is used for speech masking, because speech sound is a broadband sound (Coles, 1975). These noises are built into modern audiometers or computers used for testing.

Masking procedures, and the rationale behind their use, are well-recognised as some of the most difficult aspects of hearing tests to learn and teach (Yacullo, 2015a). Studebaker (1967) stated that “clinical masking procedures often consist of unsystematic guess-work of which there is little or no logical defence”. Similarly, Sanders (1972) began a chapter on masking with:

Of all the clinical procedures used in auditory assessment, masking is probably the most often misused and the least understood. For many clinicians the approach to masking is a haphazard hit-or-miss bit of guesswork with no basis in any set of principles. (p. 111)

Although Sanders wrote this more than forty years ago, masking remains poorly understood by some students, and even some of those who test hearing, but is well within the scope of tertiary student learning. A 1998 survey of audiological practices in the U.S. revealed many inconsistencies in masking thinking and practice, indicating that some responders did not have solid reasoning behind their masking procedures (Martin, Champlin, & Chambers, 1998). For example, one person said "crank in 65 to 80 dB (of masking noise) no matter what the (non-test ear) threshold is". The non-test ear threshold is essential to consider when applying masking noise, thus indicating a lack of understanding of how to mask.

The two principal questions concerning masking are "When to mask?" and "How much masking to use?" (Studebaker, 1964). There are a variety of procedures for masking, and several situations where masking is needed. Although procedures can be applied properly in most situations, gaps in understanding how to apply the concepts become evident when the situation requires more than a standard approach (Yacullo, 2015a).

Masking is done well when the tester can quickly identify when it is needed and apply the correct amount of noise while considering several technical factors. These factors, which will be described in more detail later, include:

- Level and frequency of sound presented to the test ear
- Type and placement of transducer (headphones or earphones)
- The occlusion effect
- Significant air bone gaps
- Which procedure to use
- Risk of overmasking
- Patient/client loudness discomfort.

(Studebaker, 1967).

Considering the number of variables that need to be considered when masking, it is unsurprising that students struggle with it. Misuse of clinical procedures occurs when the clinician does not understand how the variables above interact, that is, the above underlying concepts of masking (Yacullo, 2015a).

1.2.1 What happens if masking is done incorrectly?

Beyer (2011) wrote that inaccurate testing during masking can lead to missing a medical issue which may underlie the hearing loss. Over a three-year study, Coles (1970) found that 15% of audiograms at that time had major errors, all of which were due to incorrect or lack of masking. The most common misdiagnoses were either missing a severe air-conduction hearing loss or overestimation of (or missing) an air-bone gap. This can lead to the mismanagement of hearing loss, such as making the wrong adjustments for hearing aids.

Hearing losses that have conductive components (air-bone gaps over 20 dB) are notoriously more difficult to mask as, oftentimes, the masking noise has to be more intense which can be problematic. Obtaining accurate thresholds for each ear is essential in these cases, as it is possible that some of the conductive hearing loss can be treated with surgery (Lidén, Nilsson, & Anderson, 1959). In order to better understand the complex issues relating to masking, the concepts and procedures of masking will now be discussed in depth. The aim of this study is to evaluate a new method of teaching masking concepts, all of which are necessary to understand to perform a hearing test correctly. The focus of this study is not to teach a certain masking procedure, as the concepts of masking underlie all procedures.

1.2.2 Masking in detail

Masking is performed in both pure-tone and speech audiometry. The test signal is presented to the test ear and the masking noise is presented to the non-test ear. This section of the literature review details how the two central questions regarding masking are answered. They are: *When to mask?* and *How much masking noise to use?*

When to mask is answered by recognising when cross-hearing could be happening. When a signal in the test ear is intense enough to overcome the interaural attenuation of the transducer being used, and be audible by the non-test ear, cross-hearing is a risk. For example, if the test signal is 70 dB and the interaural attenuation is 50 dB, 20 dB of the test signal can be assumed to have crossed over from the test ear to the non-test ear. If the non-test ear's air or bone conduction threshold at the test frequency is 20 dB or better, cross-hearing is likely. Testers must therefore understand the concepts of interaural attenuation and crossover. *How much masking noise to use* is answered by first looking at the air conduction threshold of the non-test ear and deciding whether or not more noise needs to be added to compensate for the occlusion effect. An additional 10 dB is then added on as a 'safety factor' as a conservative measure. This then gives the tester the initial masking level. Testers must understand the concepts of crossover, interaural attenuation, the occlusion effect, and overmasking. The concepts will be detailed below, followed by how they are applied to pure-tone and speech masking.

1.2.3 Masking concepts.

1.2.3.1 Interaural attenuation.

The two cochleas are embedded in the temporal bones on both sides of the skull, which are connected by other cranial bones, including the parietal and occipital bones. As sound travels from one side of the head to the other, some of its energy is lost in transmission. This energy loss is measured in decibels and is called interaural attenuation (IA) (Martin

2015). A person's IA determines the portion of a signal delivered to one ear that reaches the other ear (Zwislocki, 1953). IA varies from 0 dB to 75 dB (Yacullo, 2015, p. 78) Conservative estimates are used for IA values due to inter-subject variability. It is dependent on three factors:

- Transducer type (insert earphone, supra-aural headphone, or bone conduction vibrator)
- Frequency of test tone
- Individual subject.

1.2.3.2 Crossover and cross-hearing.

Crossover occurs when the signal presented to the test ear (TE) reaches the non-test ear. The amount that crosses over is determined by the individual's interaural attenuation. However, the level of sound reaching the non-test ear (NTE) may not be audible if the person's hearing sensitivity is poor. Cross-hearing occurs when the crossed-over sound reaches the NTE at a level that is above that ear's threshold (Gelfand, 2016).

It is easy to imagine that crossover happens due to sound physically reaching one ear from the other around the outside of the skull via the air. However, crossover is known to stem primarily from bone conduction mechanisms within the skull (Zwislocki, 1953; Wegel, 1924; Studebaker, 1962; Sparrevohn, 1946; Chaiklin, 1967). Even when testing air conduction thresholds, crossover (and therefore cross-hearing) occurs through bone conduction (Martin & Blosser, 1970). This is true for both pure-tones and speech stimuli (Martin, 1974). Some sound can escape into the environment and travel around the head via the air and enter the non-test ear via the air conduction route, however, it is usually blocked from entering the NTE by the transducer in that ear (Yacullo, 2015).

Cross-hearing proves problematic during hearing testing when the tester needs to get ear specific information. Whenever there is a chance of cross-hearing, masking is necessary (Yacullo, 1996).

1.2.3.3 The occlusion effect

In 1966, Tonndorf coined the term the *occlusion effect* (OE) to describe the false improvement of bone conduction thresholds when the outer ear is covered or blocked. It can falsely improve BC thresholds by 15-20 dB for frequencies under 2000Hz (Goldstein & Hayes, 1965; Martin & Clark, 2015).

Normally, the outer ear (from the pinna up until the ear drum) acts as a high pass filter, meaning that high frequencies travel through to the middle ear and (some) low frequencies are able to escape back out through the ear canal opening (Tonndorf, 1964, 1966). When the ear canal is blocked, those sounds cannot escape into the environment and are reflected back towards the ear drum. This leads to the head vibrating more which results in louder low-frequency sounds (Zwislocki, 1953).

During masked bone conduction testing, an insert earphone or headphone is placed over the non-test ear to provide the masking noise, resulting in the OE, which must be compensated for by adding 10-20 dB of additional masking noise to the initial masking level. The higher the initial level of masking noise, the more difficult it can be to get an accurate masked bone conduction threshold.

The degree of the occlusion effect is determined by the hearing loss type, masking transducer and type of test signal. It is decreased or absent in ears with a conductive hearing loss (i.e. those with significant (15 dB or greater) air-bone gaps). If the non-test ear has a significant air-bon gap, the OE does not need to be added to the initial masking level

(Gunnar. Lidén et al., 1959) and (Martin, 1974). Studebaker (1962) suggested that the occlusion effect be added to initial masking levels to compensate for the OE for those with normal hearing or sensorineural hearing losses only (i.e. those without significant air-bone gaps). However, the tester may not know if there are significant air-bone gaps in the non-test ear, so extra masking noise for the OE is added on regardless. Secondly, the type of transducer that delivers the masking noise affects the OE (Table 1). Supra-aural headphones create a larger occlusion effect compared to insert earphones due to their larger contact area with the skull and a longer distance from ear drum to transducer. The depth of insertion of insert earphones can affect the OE: Stenfelt et al. (2007) and DeSantolo (2017) discovered that the deeper an insert earphone is placed, the smaller the occlusion effect, which is preferable for testing. Stenfelt et al. (2007) attributed this to the resonant properties of the two different parts of the ear canal. The first half of the ear canal closest to the outer ear is cartilaginous in nature and the second half leading to the ear drum is bony. Bone-conducted stimuli in an occluded ear causes movement of the ear canal walls, resulting in sound pressure in the canal. Additional sound pressure is generated in the cartilaginous portion of the ear canal which is transmitted into the cochlea. When the outer ear is occluded, as in the case of masked bone conduction testing, these sound pressure waves cannot escape out through the outer ear, and are instead funnelled into the cochlea. The more vibrations there are in an occluded ear canal, the greater the OE. If an insert earphone is inserted deeply enough to ‘fill’ the cartilaginous portion, a reduction in the OE is seen because the trapped sound waves are unable to vibrate as much. An insert earphone inserted less deeply may still ‘fill’ part of the cartilaginous portion, therefore reducing the OE. A supra-aural headphone, however, is unable to prevent the cartilaginous portion from vibrating, and these additional sound pressure waves contribute towards greater OE values. Lastly, the degree of the occlusion effect depends on the frequency being tested. Bone conduction thresholds are typically only measured at 500Hz, 1000Hz, 2000Hz and 4000Hz, unlike air conduction thresholds, which can be measured at any frequency from 125Hz to 12000Hz on a standard audiometer, and up to 16000Hz with high-frequency audiometry. The occlusion effect only affects 500Hz and 1000Hz for masked bone conduction testing due to the anatomy and physiology of the ear. The amount of additional masking noise that must be added to the initial masking level can be seen in Table 1.

Table 1: Occlusion effect values that are added to the initial masking level for bone conduction masking (Yacullo, 2009).

Extra masking noise needed to compensate for the occlusion effect			
	Non-test ear status		
	No conductive component		Conductive component of 20 dB or more
Transducer	Supra-aural headphones	Insert earphones	
Frequency			
500Hz	20 dB	10 dB	0 dB
1000Hz	10 dB	0 dB	0 dB

1.2.3.4 Central masking.

Another element to consider while masking is the phenomenon of central masking, first described by Wegel and Lane (1924). This is a worsening of threshold arising from a conflict of processing of sound from both ears in the brain. Central masking can occur for both pure-tones and speech sounds and occurs even with a low-level masking sound (Dirks & Malmquist, 1964; Gunnar. Lidén et al., 1959). Central masking results in a 5 dB threshold shift (making the threshold appear worse) but can be ignored or even subtracted from the masked results (Studebaker, 1964).

1.2.3.5 The three stages of masking: undermasking, effective masking and overmasking.

Information in this section has come from Gelfand (2016). Undermasking occurs when there is not enough masking noise to eliminate the non-test ear from responding to the test tone. During undermasking, the non-test ear is responding to the test signal. Effective masking is when the masking noise is intense enough to eliminate the non-test ear from responding to the test tone. Responses during effective masking come from the test ear at its true threshold. Overmasking is a problem during masking. It occurs when the masking noise from the non-test ear reaches the test ear and prevents it from hearing the test signal at its true threshold, masking its sensitivity look worse than it is. The higher the initial masking level, the greater the chance of overmasking. When the masker level is equal to or exceeds the bone conduction threshold in the TE plus interaural attenuation, overmasking can happen. The initial masking noise level is higher when there are air-bone gaps in the non-test ear and when the occlusion effect must be accounted for (detailed below.) Overmasking is particularly important to consider when masking.

An analogy for understanding undermasking, effective masking, and overmasking was proposed by Gelfand (2016). If the right eye is being tested and the left eye is covered by a piece of paper that does not adequately cover the eye, the left eye can still help the brain see (undermasking). If the size of the paper covers the left eye entirely, the right eye must do all the seeing alone (effective masking, represented by the plateau). Overmasking would occur if the piece of paper covering the left eye is so large that it starts to cover the right eye, the right eye will see less than it is truly able to. The three stages of masking are seen more explicitly in Hood's masking procedure but are also present in step masking, another common masking procedure. These two procedures will be detailed below.

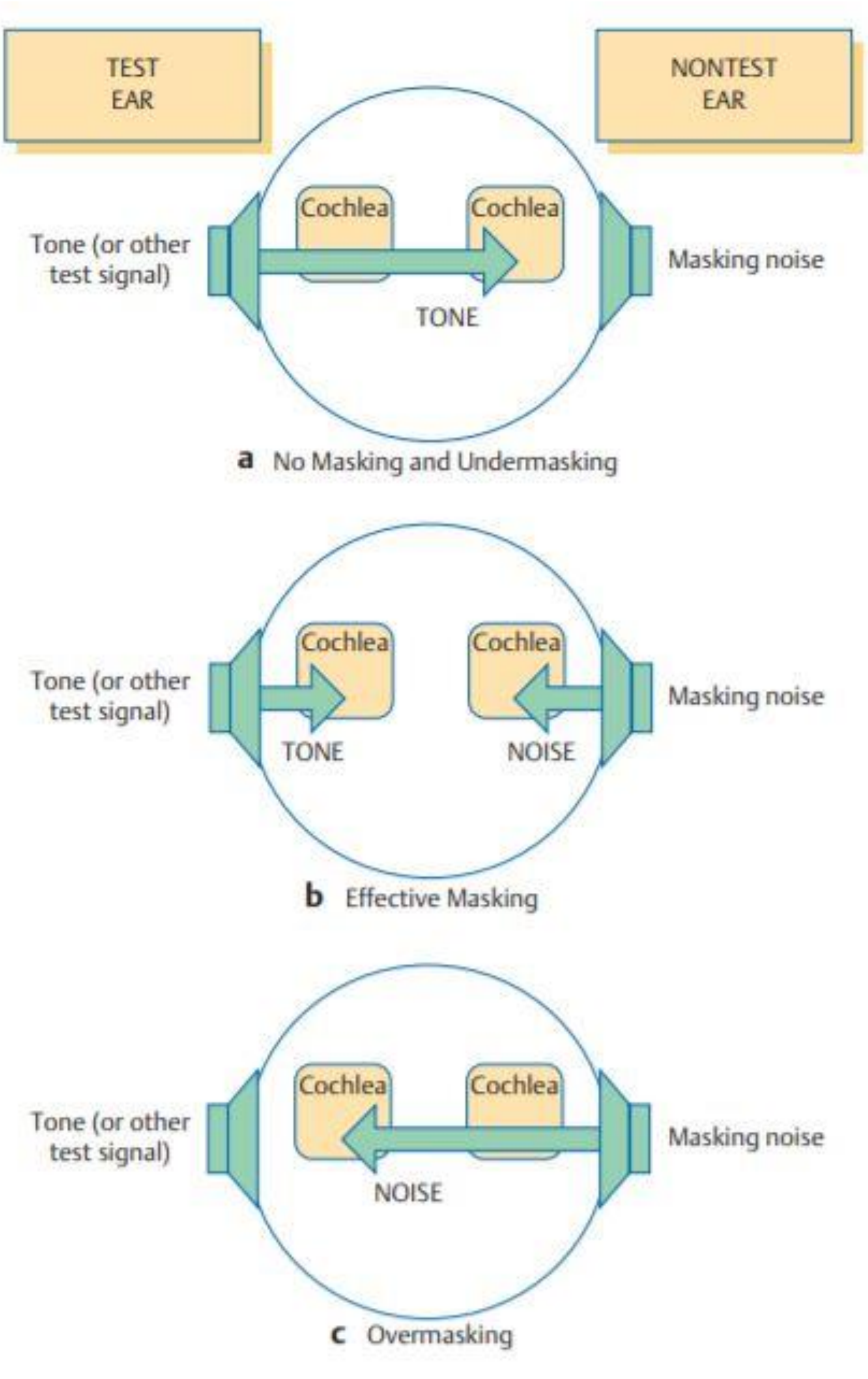


Figure 1: Undermasking, effective masking and overmasking from Gelfand (2016, p. 260). This figure helps the reader to understand how the masking noise from the non-test ear can reach the test ear (overmasking), and how the test signal to the test ear can reach the non-test ear (undermasking or no masking). Permission to reprint this image has been requested.

1.2.3.6 Masking dilemma

Closely related to overmasking is the *masking dilemma.* This happens when the minimum amount of masking required to eliminate the non-test ear's contribution to hearing the test signal is intense enough to be audible in the test ear. This term was coined by Naunton (1960) and can happen in both pure-tone and speech masking. Masking dilemmas are likely to occur when there is a high level of initial masking noise needed and relatively good bone conduction thresholds in the test ear. For example, in cases of:

- Bilateral conductive hearing loss
- Conductive hearing loss in the test ear and (at least a moderate) sensorineural hearing loss in the non-test ear (British Society of Audiology, 2012).

Knowing what configurations of hearing loss often lead to masking dilemmas helps the tester by preparing them in advance and possibly choosing a more conservative masking procedure, such as Hood's (1957) method instead of the step method. Masking dilemmas can mean that the tester cannot get masked thresholds or can only get a 15 dB plateau.

1.2.4 Masking procedure.

1.2.4.1 Recognising the need to mask pure-tone stimuli.

The first step in masking pure-tones is to check if cross-hearing could be happening, which indicates the need for masking. If the level of the test stimuli minus interaural attenuation is greater than or equal to the bone conduction threshold in the non-test ear, cross-hearing could be happening. This applies to both air and bone conduction audiometry.

Masking for pure-tone stimuli is needed if $PL(TE) - IA \geq BC(NTE)$

PL = presentation level (of test stimuli), TE = test ear, IA = interaural attenuation, BC(NTE) = bone conduction threshold in the non-test ear.

1.2.4.2 Methods of masking.

There are two popular methods of masking pure-tones: Hood’s plateau method and the step method. Both involve knowing how to apply the concepts detailed above.

Hood’s plateau method of masking.

The plateau method of masking, described as the most reliable masking technique by Coles (1970), was first described by Hood in 1957. There are several other described procedures in the literature, but the plateau method still holds strong as one of the most commonly used today. There is an emphasis on mastering this method in the University of Canterbury course, from which the audiology students in this study were recruited.

The initial masking level is determined by taking the air-conduction threshold of the non-test ear, then adding at least 10 dB, depending on whether the tester is masking air- or bone-conduction thresholds. The level of masking noise to the non-test ear is then increased in 10 dB increments while the threshold at the test ear is re-tested. It is possible that with increases in masking noise, the threshold of the test ear will worsen (increase). A plateau marks the range of *effective masking* and is reached when increases in masking noise do not increase the test ear threshold (Hood, 1957). During the plateau, which is between under- and over-masking, responses to the test stimuli are from the test ear. Hood suggested increasing the masker level in 10 dB steps while responses to the test stimuli are checked, but others have suggested 5 dB steps (College of Speech and Hearing Health Professionals of British Columbia, 2014; Martin, 1980; Yacullo, 1999). Smaller step sizes can be more accurate but may be more time consuming. For most cases, a masked threshold is accepted after a 20 dB plateau, i.e. a 20 dB increase in masking noise with no change in threshold. A 15 dB plateau may be accepted in situations where getting a 20 dB plateau is more difficult, such as in cases of hearing loss with air-bone gaps of 20 dB or greater. It is not necessary to measure the whole plateau before overmasking occurs: all the tester needs is a 15-20 dB plateau (Yacullo, 2015).

Step masking.

Step masking is a faster, less conservative way of masking pure-tone air and bone conduction thresholds. The initial masking level for this method is: the air conduction threshold of the non-test ear at the test frequency, plus 30 dB. If there is a response to the test signal (at its unmasked level) with that amount of masking, the threshold can be accepted. No plateau is sought, as is done in the Hood method. If there is no response at the unmasked threshold level, additional masking is added and the test signal level is increased.

Other procedures.

Other masking procedures have been suggested in the past (e.g. by Gunnar. Lidén et al., 1959; Martin, 1974; Smith, 1968; Turner, 2004a, 2004b; Veniar, 1965). It is unknown how much uptake there was of these suggested procedures. Turner wrote that “Our experiences indicate that students who are taught the plateau method (Hood’s technique) frequently abandon this technique when they leave the unique environment of the academic clinic.” (p. 18). This has been true in the author’s observations of clinical practice where audiologists use step masking to save time. However, Turner’s proposed masking procedure, by the author’s own admission, does not apply to all situations, which are detailed in Turner (2004b).

All masking procedures address the complex factors underlying masking to try and obtain masked thresholds without overmasking. Although the plateau method may be more time-consuming, it is understandable that it is the first-taught procedure in many audiology courses due to its conservative nature and ability to be applied to any hearing loss configuration. What is usually taught in masking, and how, will be discussed first.

The three rules of masking pure-tones.

There are three rules of masking common across pure-tone audiometry guidelines (American Speech-Language-Hearing Association, 2005; British Society of Audiology, 2016; College of Speech and Hearing Health Professionals of British Columbia, 2014; New Zealand Audiological Society, 2016). Rules like these give testers guidelines for the procedure but are not necessary (Martin, 1974).

1. Mask air conduction thresholds based on the air conduction threshold of the non-test ear
2. Mask bone conduction thresholds based on the presence of an air-bone gap in the test ear
3. Mask air conduction thresholds based on the bone conduction threshold of the non-test ear.

Rules 1 and 3 will be discussed first, as they both pertain to air conduction masking.

Air conduction thresholds of the test ear need to be masked when there is a chance that the non-test ear is the ear responding to the test signal. Air conduction (AC) thresholds can be masked on the basis of the air conduction of the non-test ear, or the bone conduction of the non-test ear.

Rule 1: Masking air conduction thresholds based on the air conduction thresholds of the non-test ear.

It is recommended to first look for the need to mask air conduction thresholds based on the air conduction threshold of the non-test ear. Hood (1957) stated that if the difference in AC thresholds between the ears at any given frequency is equal to or greater than interaural attenuation, the poorer ear's AC thresholds must be rechecked with masking.

$$\textit{Masking required if } AC(TE) - AC(NTE) \geq IA.$$

This can be checked for immediately after obtaining unmasked AC in both ears (NZAS 2016). Interestingly, several popular audiology textbooks (Gelfand, 2016; Katz, Chasin, English, Hood, & Tillery, 2015; Martin & Clark, 2015) do not mention masking AC thresholds based on the AC threshold of the non-test ear. Studebaker (1964) wrote against the practice of masking AC based on the AC of the NTE because IA is due mainly to sound travelling through the head (via bone conduction) rather than going around the head via air conduction. Instead, he proposed to mask AC based on NTE BC thresholds as this identifies the same thresholds that need to be masked, and more. Coles (1970) wrote that masking AC based on AC of the NTE was a "frequently occurring misconception" that AC masking is only needed when the difference of the AC thresholds is greater than or equal to IA.

The British Society of Audiology (2012) protocols state that "(AC for AC masking) is merely a convenient way of anticipating the need to mask in many cases" (2012). Masking AC thresholds based on the AC of the NTE features in audiological protocols by the American Speech-Language Hearing Association (2005), New Zealand Audiological Society (2016) and the University of Canterbury (2018).

In a 1998 survey of American audiometric practices, only 53% of participants responded that they masked AC based on AC if the difference was greater than 40 dB (or other nominated IA values) (Martin et al., 1998). In a similar Canadian survey, 63% of respondents used a 40 dB difference to determine whether to mask, and the remaining responders used criteria of greater than 40 dB (DeBow, 2000).

Rule 3: Masking air conduction thresholds based on the bone conduction thresholds of the non-test ear.

Less controversial than the first rule of masking is the third rule of masking. Masking air conduction thresholds is ultimately dependent on the bone conduction threshold of the non-test ear at the test frequency (Hood, 1957). AC masking based on AC thresholds is useful in clinical practice but not as essential because cross-hearing occurs via bone conduction, and therefore the BC thresholds must always be kept at the forefront of the tester's mind. If the difference between AC threshold for the test ear and bone-conduction (BC) threshold in the non-test ear equals or exceeds the inter-aural attenuation value for the transducer, cross-hearing could be happening and masking is required (New Zealand Audiological Society, 2016).

$$\textit{Masking is needed if } PL(TE) - IA \geq BC(NTE)$$

Rule 2: Masking bone conduction thresholds.

Interaural attenuation for the bone conduction vibrator is conservatively estimated at 0 dB across all frequencies. This means that no sound energy is lost between the cochleas when a sound is played through the bone conduction vibrator: i.e., a 20 dB sound played to the left ear will also arrive at 20 dB in the right cochlea. This can make it difficult to test the ears separately; an unmasked BC threshold can come from either ear (or both ears), regardless of where the transducer was placed.

Masking for bone conduction thresholds is performed on the presence of air-bone gaps. An air-bone gap (ABG) is the difference in decibels between the AC threshold and the

BC threshold in one ear at a specific frequency. Because of how sound travels through the ear, the BC threshold cannot be worse than the AC threshold in the same ear. ABGs can indicate a conductive hearing loss or cross-hearing; i.e. the unmasked BC threshold is actually from the non-test ear. If the tester comes across an ABG that is 15 dB or greater, the BC threshold must be retested with masking in the NTE (Studebaker, 1962).

$$\textit{Masking is required if } AC(TE) - BC(TE) \geq 15 \textit{ dB}$$

If the air-bone gap remains even after masking the BC, it can be concluded there is a true conductive component for that frequency in the test ear, indicating that sound is not travelling as it should from the outer ear to the inner ear. Alternatively, if the masked BC threshold changes and is within 15 dB of the AC threshold, the hearing loss can be deemed sensorineural (of cochlear or neural origin). ABGs under 15 dB are considered insignificant because of normal variability (Martin & Clark, 2015).

Hood (1957) suggested that all BC thresholds should be masked because interaural attenuation for the bone conduction vibrator is close to 0 dB. This notion has been dropped in the literature and in practice, and now it is accepted that it is efficient enough to mask BC testing when an air-bone gap of 15 dB or more is observed (Studebaker, 1967).

Large ABGs make it harder to obtain masked thresholds. Hood (1957) wrote that conductive losses greatly complicate bone conduction testing as it makes it more difficult to eliminate the NTE's contribution to the results. This means that the tester sometimes cannot eliminate the non-test ear, meaning that he or she cannot get ear-specific information (Studebaker, 1964).

In the 1998 survey of audiometric practices in the USA, only 49% of respondents consider an ABG of a specified amount (10-15 dB) when deciding the need to mask BC thresholds (Martin et al., 1998). This is a surprisingly low proportion considering the rule for bone conduction testing has existed since the 1950s. In a 2000 survey of Canadian audiometric practices, 91% reported using ABGs to decide whether to mask BC (DeBow, 2000).

1.2.4.3 Masking speech stimuli.

The air and bone conduction tests detailed above measure a person's threshold for pure-tone signals. In real life, however, people do not often encounter pure-tones. Speech, music and environmental sounds are quickly-changing, complex sounds. Speech audiometry is particularly useful for investigating how a person can detect and process words. The most common speech test used in New Zealand is the Word Recognition Score test (WRS). This uses monosyllabic words, such as *sip* and *coat*, which the person then repeats back. Each ear is tested separately and masking must be applied to the non-test ear when cross-hearing is possible (New Zealand Audiological Society, 2016). Results from speech testing are indicative of how well a person can hear and process speech in ideal conditions (sound-proofed room, no background noise, one word at a time).

If the level of speech is strong enough to overcome interaural attenuation and reach the cochlea of the NTE, masking is indicated. Because speech is a broadband signal, bone conduction thresholds at all frequencies of the NTE must be considered. Even if just one BC threshold falls under this criterion, masking noise must be introduced (Yacullo, 1999). Because words are not frequency specific like pure-tones, a different type of masking noise is applied. Broadband noise is used to mask speech because it encompasses sound energy across a wide range of frequencies (Martin & Clark, 2015).

$$\textit{Masking is needed if } PL(TE) - IA \geq \textit{ best BC in NTE}$$

If cross-hearing is suspected, masking is immediately applied; unmasked thresholds are not sought before masked ones for the WRS like in pure-tone testing. Masking for the

WRS does not use a plateau method like pure-tone testing because it is not a threshold-seeking test. The level of masking noise applied depends on the bone conduction thresholds in the non-test ear, interaural attenuation of the transducer presenting the speech stimuli, and any air-bone gaps that are equal to or greater than 15 dB (New Zealand Audiological Society, 2016). Because the masking level for the WRS is not varied depending on the response to the test signal like for pure-tone testing, it is comparably less complicated. However, in other countries where other speech tests are used, the level of masking is varied (e.g. the Speech Reception Threshold test (American Speech-Language-Hearing Association, 1988)).

1.2.5 What is usually taught, and how?

Masking is taught in the first semester of audiology courses. In the University of Canterbury audiology course, resources to teach masking reference textbooks such as Yacullo (2015) and Gelfand (2016) as well as professorial experience of the instructor. The theory of masking is taught in a lecture series covering IA, crossover, cross-hearing, the OE, and the stages of masking. The procedural, practical learning happens in a tutorial with audiometers with a different instructor. Both the lecture series and the practical learning at UC are centred upon learning, memorising and applying the three rules of masking, and other rules for speech masking, as detailed above. Students are encouraged to practise masking and other audiometric procedures using *Parrot*, a simulation software. Students have clinical placements during the two years of the course where they have opportunities to practise the procedure. Masking is assessed by a written test in the first semester, and by practical tests in the middle of the first-year. Students must be able to understand the underlying concepts of masking and be able to perform the steps of a masking procedure correctly in order to pass these assessments

Lecture slides on masking from other universities that are available from online searches indicate that the same concepts listed above by Studebaker (1967) are covered in masking lectures (Ozarks Technical Community College, 2014; University of Florida, n.d. ; University of Kentucky, 2015; Utah State University, 2011). Similar formulae for learning masking are also seen in these lectures. Learning a masking procedure is not necessarily difficult in itself and does not require a holistic understanding of the underlying concepts. Martin (1980) wrote “One reason why masking may be poorly understood is that clinicians tend to perform it before they comprehend its meaning” (p. 112). Failure to acquire this understanding can lead to difficulties in hearing testing for complex cases. Ensuring that masking is taught effectively therefore requires consideration of the mode of teaching employed (e.g. lecture, lab and/or simulation), as each have their advantages and disadvantages.

1.2.6 How can masking be taught differently?

Masking could be taught differently by using a computer-based simulator in a lab-style class, guided by a tutor. Allowing each student to use the software in class could make the students active participants instead of passively absorbing information communicated to them. Using software like this could help students deepen their knowledge of masking concepts. In early 2018, first-year audiology students at UC completed a written test as part the *Diagnostic Audiology* course, run by Dr Alison Cook. A variety of issues with masking were identified, suggesting that the concepts described above had not been understood well by the students in this course. Some of the concepts students struggled with included:

- When to mask for bone conduction
- Calculation of overmasking
- Which audiometric configurations a masking dilemma is likely to occur in
- Central masking
- Interaural attenuation
- Plateau width

- The occlusion effect
- Maximum masking calculations
- Initial masking levels
- Step sizes to get a plateau
- When and why to mask in speech audiometry.

The amount of masking concepts that were not well understood by these first-year students indicates that perhaps the current mode of teaching masking (via lectures, then a practical tutorial) is not sufficient. Because the current project focussed on creating and piloting new resources to teach masking, it was decided to teach the concepts of masking without referring to the classic three rules. Using maskME, a novel piece of software designed to teach masking which will be piloted in this study, students are able to see how factors such as the occlusion effect and overmasking affect the procedure and results.

1.3 Teaching methods

A goal-orientated lesson plan helps both the teacher and students stay focussed. Styles of teaching vary according to teacher preference and the content of the course. Kirkwood and Price (2013) argued that tertiary lesson plans should be predominately learner-focussed as opposed to teacher-focussed. Although some aspects of a teacher-focussed style (e.g. transmission of information via a lecture) are likely essential, it must be ensured that the focus of the lesson is the promotion of conceptual understanding. Incorporating this approach into the lesson plan for masking will ensure that the lesson is student-centred and that concepts are introduced in an accessible manner that students can actively engage with. Activities such as summarising concepts in writing or comparing notes with a partner are examples of active learning that involve all students.

Englund, Olofsson, and Price (2017) agreed with Kirkwood, stating that a “student centred approach is consistently viewed as more sophisticated than a teacher-centred approach” (p. 74). Student centred approaches allow students to take the lead and demonstrate their understanding. Anticipating student needs for understanding masking will help develop a more focussed lesson plan and associated resources. Struyven, Dochy, and Janssens (2008)’s study on whether students prefer traditional lecture-taught classes or active-learning classes revealed that students in the lecture-taught group rated their learning experience significantly higher and performed better in assessment. This study revealed that finding a balance between traditional lecture-taught (teacher-centred) and active learning (student-centred) lessons may be challenging.

1.3.1 Using technology in education.

Technology can be used in a variety of ways to deliver information and to simulate hands-on practice in education. If used purposefully, it can enhance student engagement and learning outcomes. Advances in technology have given teachers new tools to create more diverse and engaging learning environments. Englund et al. (2017) argued that technology needs to be used in a student-centred fashion and Kirkwood and Price (2013) raised concerns about teachers using technology for the sake of it, rather than using it for specific learning goals: “technology-led innovations do not in themselves lead to improved educational practices” (p. 333). These are important considerations to be made when planning a lesson: the use of technology should be designated for specific learning goals, and ultimately for the transfer of knowledge and skills to patients or clients (Botezatu et al., 2010; Jansen, 2015).

1.3.1.1 Computer-based simulator use in healthcare education.

Computer-based simulators (CBSs) are a form of technology that have been used with success in healthcare education. CBSs can be defined as interactive simulations of real-life scenarios for the purpose of education, training or assessment (Ellaway & Masters, 2008).

Brigden and Dangerfield (2008) and Lateef (2010) listed several reasons why simulations can be beneficial for learning: they provide a safe space for the student to fail and repeat, give feedback, offer exposure to rare conditions and provide curriculum integration. Gaba (2004) noted that simulators do not necessarily have to be used in a hands-on manner for students to get benefit; students can also learn by simply viewing a simulator used as a demonstration. For example, Botezatu et al. (2010) used a live demonstration of a CBS to medical students to familiarise themselves with the software before self-directed practise. Some CBSs are designed as games and Sitzmann (2011)'s meta-analysis on the effectiveness of computer-based game simulations revealed that those who received simulation training had higher levels of declarative knowledge (memory of facts and principles) and retention than control groups.

1.3.1.2 Computer-based simulators in audiological education.

Computer-based simulators in audiology education allow students to practise their audiometric skills in a safe and standardised environment. This can build confidence and help students identify gaps in their knowledge. Simulations can also take the form of simulated patients (actors) and mannequins and, although they do not replace the teacher, can be an effective teaching tool. Ten studies have investigated the effects of simulation training on audiology education, and all but one found have found support for the continued use of CBSs in training. They are detailed below.

Two studies which used subjective measures to evaluate CBSs are by Wilson, Hill, Hughes, Sher, and Laplante-Levesque (2010) and Sistrunk (2002). Wilson et al. (2010) found that students had significantly positive experiences with the CBS in terms of performing a basic audiometric assessment, including masking. Results of this study are consistent with Sistrunk (2002)'s, who found that students enjoyed using the CBS, would recommend it, and believe that it helps in developing basic clinical skills. Including a subjective measure in the current research is important because it is vital to know if the students enjoy using the CBS and find it easy to use.

Measuring benefit with objective measures such as tests is essential for validating the use of a CBS as an educational tool. Dzulkarnain, Wan Mhd Pandi, Wilson, Bradley, and Sapian (2014), Durham, Thelin, Muenchen, and Halpin (1994), and Lieberth and Martin (2005)'s studies feature practical tests as objective measures.

Lieberth and Martin (2005) discovered that skills gained using the CBS did transfer to skills in performing a hearing test on the audiometer. However, the statistical significance of this difference is not mentioned, and the difference in means between the group which trained on the CBS and the group which trained on the audiometer is just 1.2%. There was also no pre-test measure. Two strengths of this study were that the participant size was large (197), and the comprehensive methodology including the recruitment of 100 non-audiology (novice) student participants. The novices received a similar intervention as the audiology students in the study and had similar mean scores on the final hearing test: 73.35% compared to 78.95% for the audiology students. These are encouraging results that indicate that teaching novices audiology concepts and practice can be done after a simple intervention. Of these ten studies in audiology education, only Lieberth and Martin (2005) and Guard (2013) used novice participants to test simulators.

In a study by Durham et al. (1994), a CBS was created to practise visual reinforcement audiometry, which is used to obtain behavioural thresholds from children under the age of two and a half years. Results were compared between a group who received four and a half hours of instruction on a CBS and a control group that received no CBS training. Those in the experimental group performed significantly better than those in the control group. This study's strength was in its study design with both a pre-test and post-test measure, however, the small number of participants (eight) was a limitation.

Dzulkarnain et al. (2014) conducted a study to evaluate a CBS for practising evaluating auditory brainstem response (ABR) waveforms. The study design allowed the authors to compare several different training conditions. This was the only study to find no significant benefit for the use of the CBS as an educational tool. The authors were surprised by this finding as it did not fit with the general body of literature which supports the use of CBSs. The authors proposed that the type of feedback within the CBS could have limited the students' performance. A systematic review of simulated learning environments in audiology education was published by some of the same authors of the above study and found evidence to support the use of CBSs as an effective learning tool (Dzulkarnain et al., 2014).

1.3.1.2.1 Evaluation of the Clinical Audiology Simulator at the University of Canterbury (UC).

In 2013 a PhD thesis titled *Improving Clinical Education Through the Use of Virtual Patient-based Computer Simulations* was published by Heitz, a student of Human Interface Technology at UC. Heitz created a CBS to be used in audiology education which was evaluated by four Master of Audiology students at UC: Guard (2013), Howland (2012), Sanderson (2012), and William (2013). Each student evaluated how the software could be used to teach various aspects of audiometry.

Sanderson (2012)'s pilot study of the Clinical Audiology Simulator (CAS) evaluated basic audiometry skills. Discouragingly, at the first assessment, those who had received simulation training did not perform significantly better than those who had not had the training. However, 91.7% of the participants agreed that their abilities to perform masking had improved as a result of using the simulator. In a questionnaire, the majority of students rated the CBS as, at least, *moderately useful* as an effective educational tool, consistent with Wilson et al. (2010) and Sistrunk (2002). Part of the training involved a four-hour tutorial on masking which speaks to the complexity of this aspect of hearing testing.

Howland (2012) evaluated case history taking skills and, although the effect size was small, found improvements in some areas (e.g. confidence, accuracy, efficiency) at various combinations of the three assessment points. She asked the two groups of audiology student participants to rate the perceived usefulness of CAS on a 7-point Likert scale and the mean scores were 4 and 5.4, indicating a moderately positive experience. She also discovered that using CAS had a (self-reported) positive impact on participants' confidence taking a case history.

Both Howland and Sanderson reported issues with participants committing to hours of self-practice on the CAS, then not completing it. Sanderson's participants were instructed to practise on CAS for an hour per day over two weeks. Despite agreeing to this instruction, participants used the simulator for approximately two hours each, and sometimes with a partner. Participants commented that the simulator would often crash and that the underlying course load was already significant. Howland also raised the issue of participants not completing the two hours of practice they had committed to in their spare time. She offered a voluntary supplementary tutorial but only one person attended it. Some suggested reasons for this included "all participants were extremely busy with other coursework" or due to a "lack of interest in the task" (Sanderson, 2012, p. 78).

Guard (2013) found that formative feedback in CAS had a large positive effect on learning basic pure-tone audiometry skills when compared to basic summative feedback. Guard's research is valuable because the participants had little to no prior knowledge of audiology as they were speech and language therapy students. Using participants with no prior experience of audiometry is valuable as it gives the researcher the experience of working with 'blank slates' which is similar to teaching masking to first-year students in the first few weeks of the course. Participants were emailed guidelines for performing pure-tone audiometry the day before their training session with CAS, then had to complete four cases and then a written assessment. The assessment mean scores were 48.77% and 69.6% for the summative and formative groups respectively. Guard's participant feedback was useful and showed that many students had difficulties with masking: "In particular, "masking prompts were difficult to understand" and "masking concept was difficult to understand."" (2013, p. 47). The novice participants in her study with CAS reacted positively to the software and recognised how it could be useful as an education tool.

William (2013) found that audiology students who used the CBS significantly improved their training transfer skills for audiometry and diagnostic audiology. For speech therapy students with a basic background in audiology, significant improvements in declarative knowledge were found. William did not get the results he expected, and it was suggested that the final assessment was too difficult, which influenced the results.

Some common issues with CAS were raised in the four theses:

- Bugs in the software which led to display issues and freezing during cases
- Constant and time-consuming refinement of the software
- Participants struggling to practise using the simulator in their spare time or lack of access on personal computers (the CBS was only installed on six computers on campus)
- Small participant numbers due to the small intake of the course
- Feedback that was not specific or clear enough.

Despite this, there were encouraging comments about the simulator from participants who liked the layout, found it easy to use, and thought it was a useful way to learn.

The ten studies reviewed above show that simulation can be used for positive effect in audiology education. The four theses completed at the University of Canterbury are particularly relevant to the current study due to a similar participant population, timeframe and methodology. Issues raised in these projects will be considered as the current research develops as it is possible that similar problems will arise.

1.3.1.2.2 Audiometry simulators.

A summary of eight audiometry simulators either mentioned in the literature or available online are detailed below, including screenshots. These are provided to give the reader an overview of what current simulators look like and can offer those who want to practise their pure-tone audiometry skills, including masking. Parrot (Figure 9) is the most commonly used simulator by audiology students at the University of Canterbury and is used in assessments. Two of the simulators below have been evaluated in studies: the Clinical Audiometry Simulator (Heitz, 2013) and Parrot (Townsend & Olsen, 2002).

Clinical Audiometry Simulator (CAS)

The CAS was developed at the University of Canterbury by Alexandre Heitz for his PhD in Human Interface Technology (2013). It has not been used since approximately 2013 and is not publicly available.

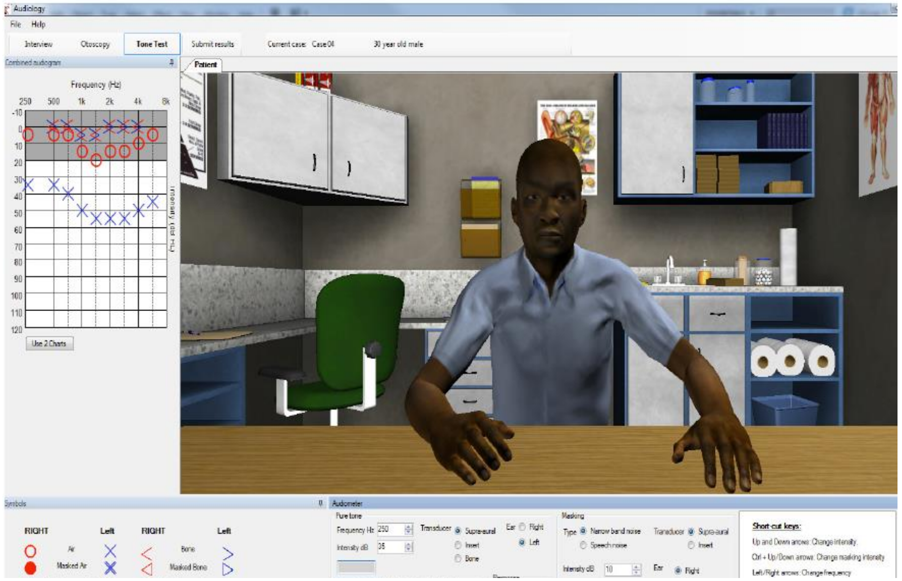


Figure 2: Screenshot of the Clinical Audiometry Simulator from Sanderson (2012. p. 29). Most other programmes only display the audiogram, but CAS shows the client in a clinical room.

Audiometer Simulator

Created by the U.S. company CounselEAR (2006), this simulator is free to use and has a variety of hearing losses that can be plotted. The response by the "patient" is slow to appear after presenting a test signal, but it has a clear and simple design.

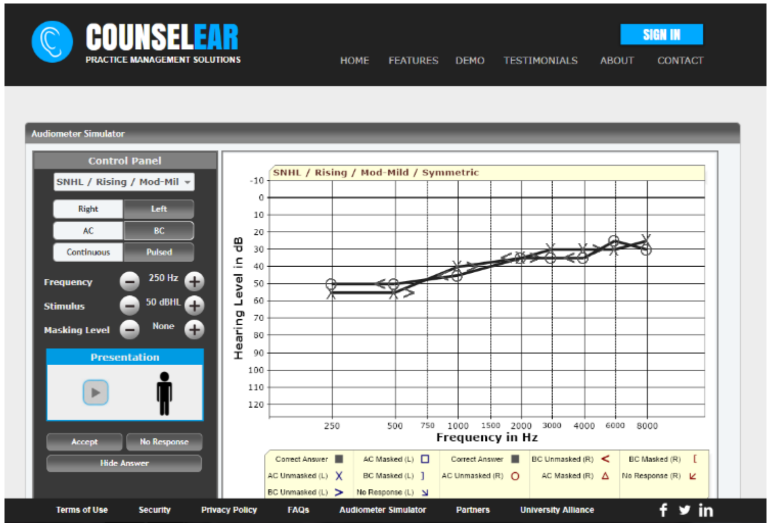


Figure 3: The answer screen for the Audiometer Simulator by CounselEAR.

AudSim Flex Audiometry Simulator

Created by AudSim (2014), the AudSim Flex costs approximately $20 USD for a single user license. It has several modes to help learning, such as the threshold assistant mode to practise obtaining an (unmasked) threshold, and an exam mode that can be used by the instructor.

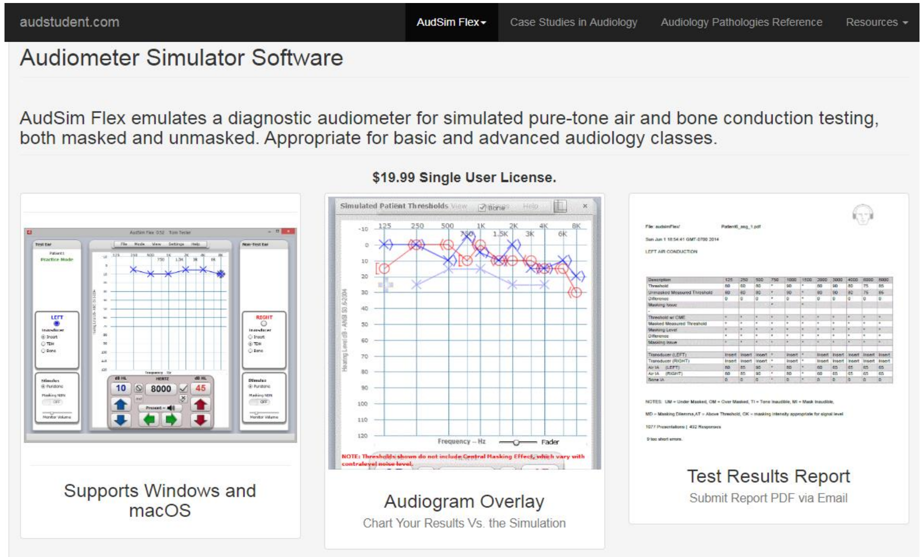


Figure 4: AudSim page explaining software with several screenshots to potential buyers.

AudSim MaskCalc

Available for free online, MaskCalc by AudSim (2015) is a tool designed to help users determine what masking level to use. Although there are instructions for use, this tool is not as advanced or easy to use as the AudSim Flex Audiometry Simulator.

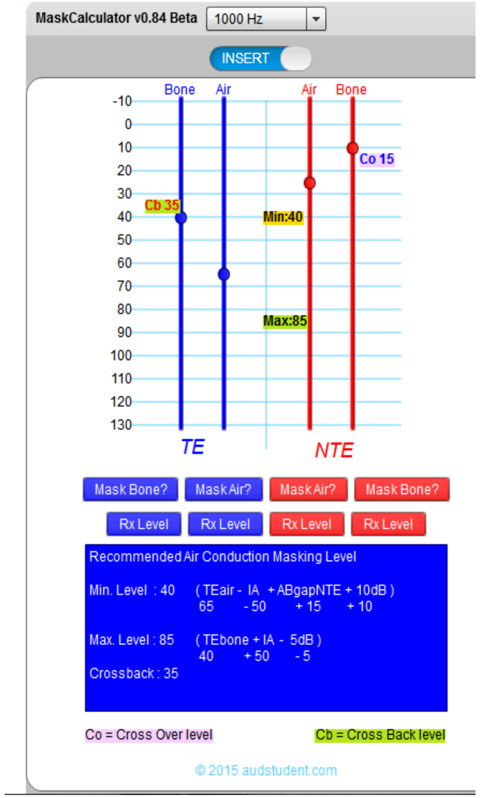


Figure 5: MaskCalc by AudSim.

Otis – The Virtual Patient

Developed by German, English and Swiss collaborators, Otis costs between $150 and $500 USD, depending on the edition of the software. It provides photos of tympanic membranes and case histories for each case, and provides instant feedback (Innoforce, n.d.).

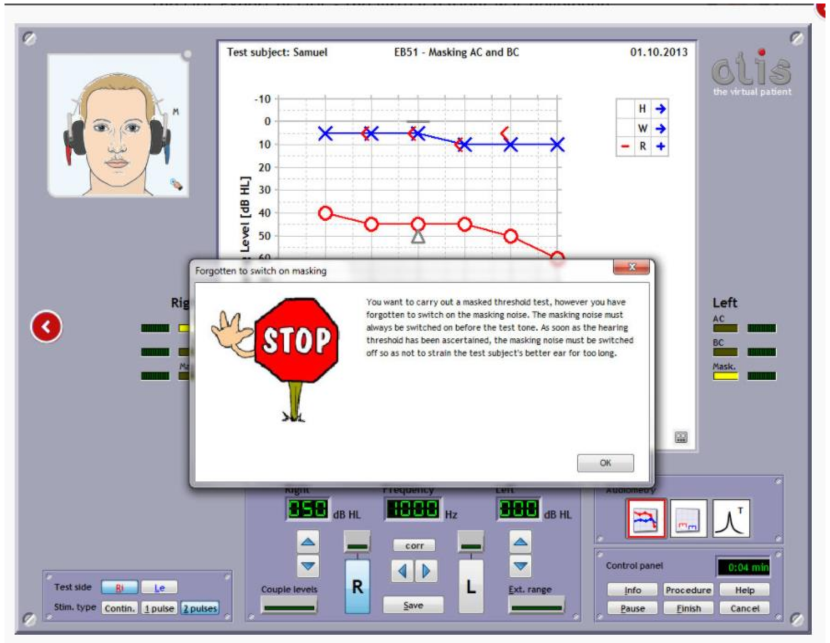


Figure 6: Otis during a hearing test showing some feedback to the user.

Audiometer Simulator

Created by Steffen et al. (2011), the Audiometer Simulator is freely available online and can be used in English, French, German and Portuguese. It has a simple and easy-to-use interface.

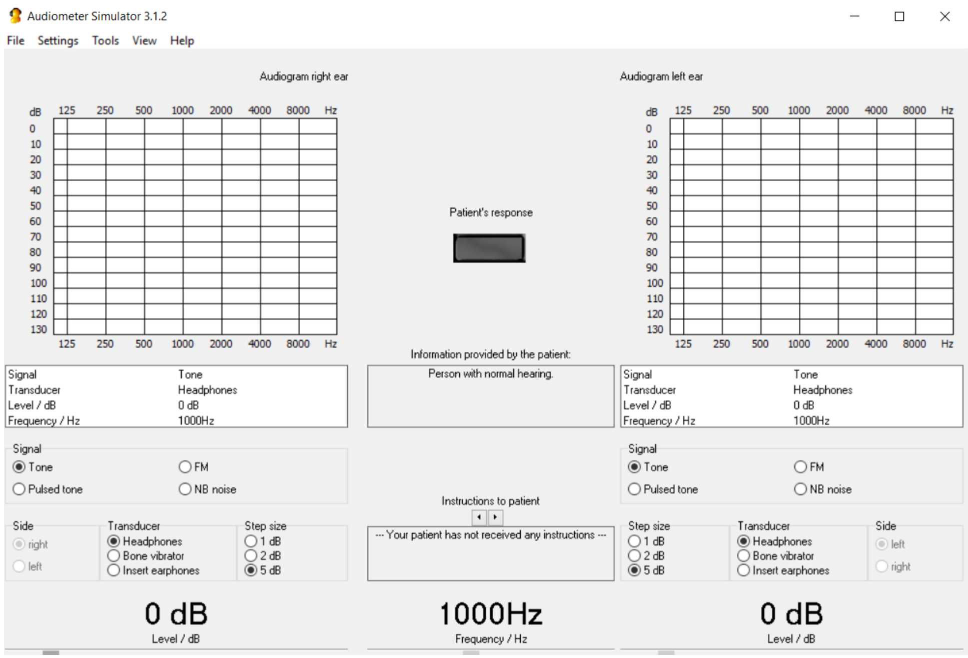


Figure 7: Audiometer Simulator interface.

Manchester University Pure Tone Audiometry Simulator

Free to access from the Manchester University website, the PTA Simulator designed by Wilding (2016) also has a simple interface.

Figure 8: The PTA Simulator's interface.

Parrot: The Audiology Clinic

Used by audiology students at UC for audiometry practice and assessment (including all audiology student participants in this study), this software is colourful and interactive, albeit dated. It costs between $39 and $950 depending on the license type (Townsend & Olsen, 2002).

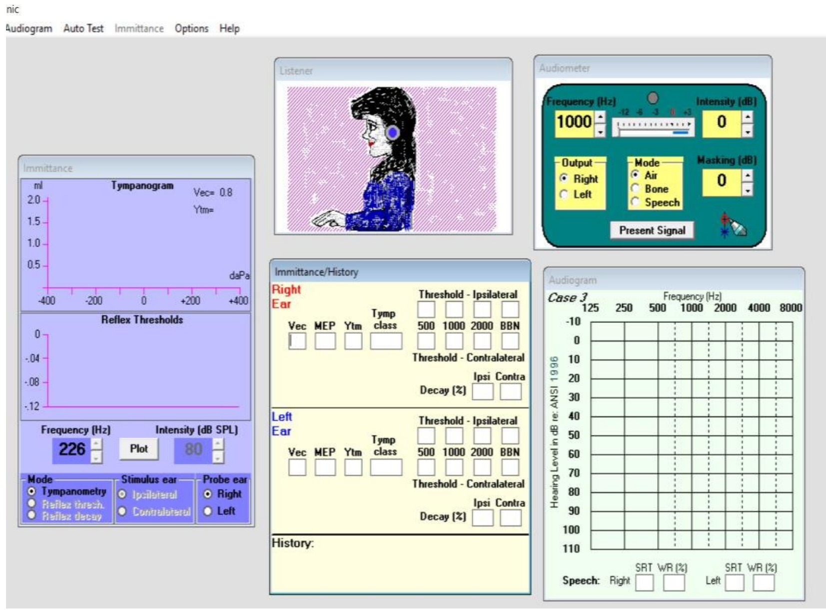


Figure 9: Parrot's user interface.

maskME

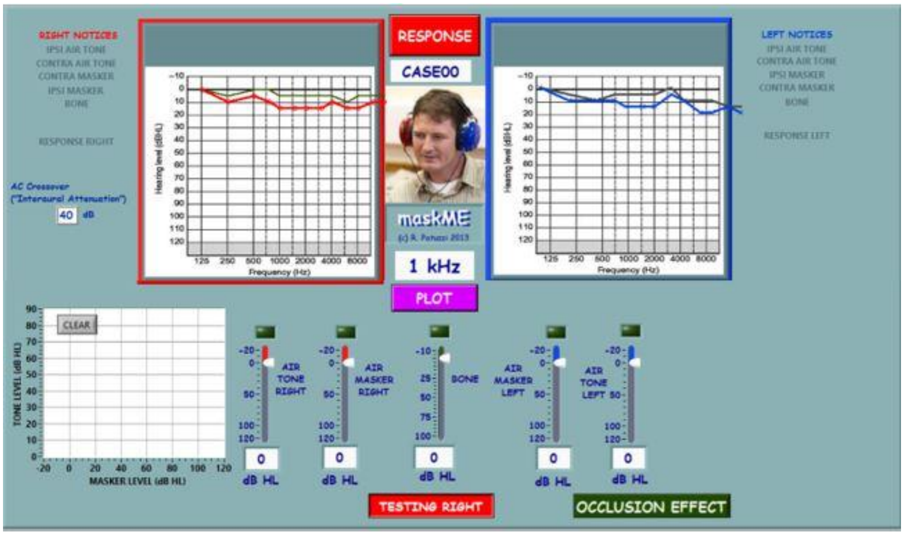


Figure 10: maskME front panel. More detail regarding the front panel can be found in Figure 12 in Methods.

maskME is the computer-based simulator that will be used in the present study. It was first created by Dr Robert Patuzzi in 2005 at the University of Western Australia and was trialled over several tutorials with audiology students, but is not publicly available. maskME was designed to help users visualise the underlying concepts of masking such as crossover, cross-hearing, overmasking and the plateau. The idea behind maskME was to help audiology students more deeply understand the concepts of masking by providing users with new visual representations of these concepts.

The benefit to using maskME over any of the currently available software is that it more overtly displays some masking concepts and was able to be customised by the primary supervisor of this study. This allowed the research team to have some control over how certain concepts were illustrated by maskME. The author trialled all freely available audiometry simulators and created Table 2, noting whether they visually demonstrated the following masking concepts or not: crossover, cross-hearing, the plateau, undermasking, overmasking and the occlusion effect. Only two simulators, apart from maskME, had some way of visually representing one or two of the concepts (Parrot and MaskCalc).

Table 2: Table comparing nine audiometry simulators and their ability to visually demonstrate six concepts of masking.

Visual representation of masking concepts of audiomtery simulators						
Simulator name	**Crossover**	**Cross hearing**	**The plateau**	**Undermasking**	**Overmasking**	**The occlusion effect**
Clinical Audiometry Simulator	Not available					
CounselEAR						
AudSim Audiometry Simulator	Not available for free online					
MaskCalc by AudSim	Yes	No	No	No	Yes	No
Otis	Not available for free online					
Audiometry Simulator - Bern University Hospital	No	No	No	No	No	No
Manchester University Pure Tone Audiometry Simulator	No	No	No	No	No	No
Parrot	Yes	No	No	No	No	No
maskME	Yes	Yes	Yes	Yes	Yes	Yes

1.3.1.3 Computer-based games.

Another form of incorporating technology in the classroom is by using computer-based games or quizzes. Several studies over the past six years have found that students highly enjoy game-based quizzes in class (Aktekin, Çelebi, & Aktekin, 2018; Bawa, 2018; Ismail & Mohammad, 2017; Salas-Morera, Arauzo-Azofra, & García-Hernández, 2012). Kahoots are multiple-choice quizzes where players answer questions on their mobile phones or on a computer. They engage learners by using bold colours and fun music, enhancing the learning experience (Boden & Hart, 2018). Questions are displayed on a projected screen then players are given a chosen period (e.g. 20 seconds) to choose an answer. The correct answer is then displayed on the screen with the names of the three players who answered correctly the quickest. Bawa (2018) tested Kahoots at an American university using a mixed method design and found that the group that was exposed to Kahoots during class had significantly higher test results than the control group, who received traditional instruction. Kahoots quizzes can be incorporated into classes to be a fast, fun and unpressured way to review the concepts introduced. The Kahoot website allows answers to be formally marked, as in Ismail and Mohammad (2017), if the lecturer wishes.

1.3.2 Assessment planning.

Scalese, Obeso, and Issenberg (2008) highlighted the importance of measuring progress to ensure that the education is orientated towards specific goals. Measuring academic milestones is done through assessment, which makes the content students have learned visible to themselves and their teacher (Keeley, Eberle, & Farrin, 2005), and make students explicitly aware of what is expected of them (Yorke, 2003). Cook and Triola (2009) reminded educators to have goal-orientated assessments by asking the question “How and for what purpose is assessment performed?” (p. 304). Most importantly, information garnered from assessments can help the educator adjust their instructional strategies to meet student needs (Keeley et al., 2005; Yorke, 2003).

Miller (1990) created a framework for clinical assessment which assess different domains of competence:

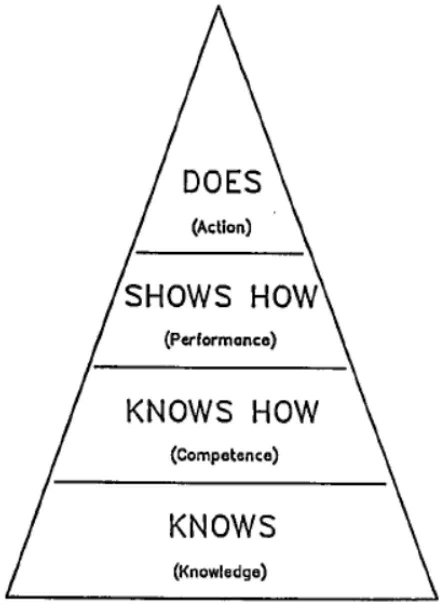


Figure 11: Miller's framework for clinical assessment (1990.)

The purpose of assessment in the present project is to both assess the ability to reproduce information presented in the sessions (Miller's *know*) and the ability to apply it to modified situations (Miller's *knows how*). Assessments need to cover the same concepts and be of equal level of difficulty. Because the purpose of this project is not to teach the procedure(s) of masking or evaluate how it is done in a real, clinical setting, participants will not be assessed on *shows how* or *does*: i.e. their declarative knowledge. Considering this framework will help direct the type of questions asked in the novel assessments used in the current study.

There is a plethora of assessment tools available to measure learning goals, such as essays, oral exams, probes, presentations, practical tests, quizzes, and assignments. Written tests are a common form of assessment to measure declarative knowledge (Miller's "*knows*"). Sitzmann (2011) wrote that declarative knowledge assessments were designed to capture what participants remembered about concepts presented during training and were always written tests. Written tests are common in the audiology course at UC and were therefore appropriate for this project.

The timing of assessment is another factor to consider. There is no gold-standard approach and several different timeframes have been used in the studies reviewed. Sitzmann (2011) investigated how studies measured retention and found that most studies had post-intervention assessments between one and four weeks after the end of training. Retention was defined as delayed measures of declarative knowledge. In research projects by William, Sanderson and Howland (2012-2013) using the Clinical Audiometry Simulator at UC, assessments were staged two weeks apart. Conversely, in studies by Alanazi (2016) and Guard (2013), assessments were carried out immediately after intervention. Assessments were also done one day after the intervention, such as in Guard (2013) and Dzulkarnain et al. (2014).

1.4 Rationale for the present study

Rated as one of the most confusing aspects of audiological education by students (Turner, 2004), revisiting the teaching of masking merits its own focussed project. Audiology students need to have a deep understanding of the concepts underlying masking procedures to quickly and effectively complete audiometry. Only with accurate ear-specific information, can appropriate recommendations for management or treatment of hearing loss be made. Answering the two key questions about masking *when to mask?* and *how much masking to use?* requires an in-depth knowledge of interaural attenuation, crossover, cross-hearing, the occlusion effect and overmasking. These concepts must be considered every time masking is indicated during a hearing test. Masking is performed on a daily basis for most practising audiologists, masking this study particularly clinically relevant. Emerging research in audiology education piloting the use of clinical simulators indicates that audiology students could benefit greatly. However, more research is needed in audiological education evaluating whether using a computer-based simulator as a learning tool is actually beneficial.

The research reviewed highlights the importance for creating engaging lessons and assessments with appropriate use of technology to help students learn. Validating the effectiveness of resources in audiology education can be done with both objective and subjective measures to evaluate whether they positively affect student learning.

1.5 Research questions and hypotheses

Research question 1.

Does audiology student participants' knowledge of the concepts of masking improve after a session on masking using maskME?

This will be answered by administering paper-based quizzes with short-answer answer and multi-choice questions on content covered in the sessions. A quiz will be administered before the session to establish a base-line measure, then the quiz will be administered again at the end of the session for a post-session measure.

Based on previous research (Durham et al., 1994; Lieberth & Martin, 2005; Sitzmann, 2011), it is hypothesised that the post-session quiz scores will be significantly higher than the pre-session quiz scores.

Research question 2.

How does a group of non-audiology students score on a masking quiz following a session on hearing and masking using maskME?

This will be answered by administering a paper-based quiz to the group after a session with both audiology students and novices and comparing results between the groups.

Because there is not enough previous research in audiology education that compares novices to audiology students, no hypothesis will be made.

Research question 3.

Do participants perceive the masking session and maskME as useful for learning masking concepts?

This will be answered by analysing answers from a paper questionnaire which will be given to students at the end of the second session. Questions will be answered using a Likert scale. The questionnaire will also provide an opportunity for open-ended feedback on how to improve the lessons.

Based on previous research (Guard, 2013; Howland, 2012; Sanderson, 2012; Sistrunk, 2002; Wilson et al., 2010) it is hypothesised that participants will perceive the masking session and maskME as beneficial for learning masking concepts.

2 Method

The purpose of the current study was to develop and test a new way of teaching masking to audiology students, including the use of a specifically designed piece of software, maskME. The lesson plan was piloted with both audiology students and novice students over four sessions. First the research design will be discussed, followed by how participants were recruited, followed by the development of: maskME, the learning outcomes, the workbook, the session structure, the PowerPoints, the Kahoots quizzes, and the quiz and the questionnaire.

2.1 Research design

Table 3 shows the research design for all groups in the present study. The study design for the audiology student groups consisted of a pre-treatment assessment (a quiz), the treatment (the masking session) followed by a second assessment (the same quiz) and a questionnaire, all within the same session. Quiz results would provide objective data on knowledge understanding and questionnaire responses would provide qualitative information regarding the experience of the session. The study design was similar to that of previously published research (Guard, 2013; Howland, 2012; Sanderson, 2012; William, 2013; Wilson et al., 2010). The study design for novices (i.e. non-audiology student participants) was the same as above but without the first assessment and with an additional presentation introducing the groups to hearing and hearing testing. The term *session* was chosen as an alternative to *lesson* or *class*, and is used throughout this study.

Table 3: Research block design by group and session detailing what intervention and assessments were carried out

Group 1 / Session 1. Second-year audiology students			
Quiz A	Masking lecture and activities	Quiz A (repeat)	Questionnaire

Group 2 / Session 2. First-year audiology students			
Quiz B	Masking lecture and activities	Quiz B (repeat)	Questionnaire

Group 3 / Session 3. Novice participants			
Introduction to hearing and hearing testing	Masking lecture and activities	Quiz C	Questionnaire

Groups 4 and 5 / Session 4. Second-year and first-year audiology students			
Quiz C	Masking lecture and activities	Quiz C (repeat)	Questionnaire

Group 6 / Session 4. Novice participants			
Introduction to hearing and hearing testing	Masking lecture and activities	Quiz C	Questionnaire

2.2 Participants

Both audiology students and novice participants were recruited for this study. There were 48 unique participants, 25 novice participants and 23 audiology students, but 56 participants in total, because eight audiology students each attended two sessions. The first three sessions were each attended by only one group and three of the six groups attended the fourth session. An overview of which participants attended which session can be seen below in Table 4. Detailed demographic data are presented in Tables 6-8.

2.2.1 Audiology student participants.

Groups 1, 2, 4 and 5 participants

All students in both years of the Master of Audiology course at the University of Canterbury were invited to participate using paper advertisements on campus, via Facebook and through word of mouth (Appendices B1, B2 and B5). The course is a two-year full-time programme with up to 16 students in each year group. Students must have at least a bachelor’s degree (in any discipline) to be admitted to the course. At the time of the masking sessions, the first-year students each had accrued approximately 16 days of practical, supervised experience, and the second-year students approximately 80 days. All audiology students had completed, or were in the process of completing, courses which include concepts of masking, and as such, could be assumed to have at least a basic understanding of the concepts of masking that were addressed in the sessions, and some familiarity with masking procedures.

2.2.2 Novice participants.

In contrast, the novice participants had no prior experience with audiometry. There were two groups of novice participants: Groups 3 and 6, totalling 25 people. In absence of new first semester audiology students, novices were used to evaluate how well they could learn the basic concepts of masking in a session using maskME. The novices completed one quiz each after each session and did not complete a pre-session quiz as a baseline measure, as the audiology student participants did.

Group 3 participants.

Participants in Group 3 were recruited from the University of Canterbury campus using paper advertisements (Appendix B3), and via the New Zealand Institute of Language, Brain and Behaviour Facebook page. Inclusion criterion was anyone who had not had any experience with learning about hearing or hearing testing. The advertisements were placed across various areas of campus with the aim of recruiting participants with a variety of educational backgrounds. It was hoped that at least 16 participants would be recruited in order to be representative of the intake of the course.

Unfortunately, despite eleven people confirming their participation in Session 3, only four attended. Three were students, studying towards a Bachelor of Engineering, a Doctorate of History, and a Masters of Financial Management. One participant was not currently a student but had a Masters of Heritage Management.

Group 6 participants.

The recruitment for Group 6 participants was the same as for Group 3. Twenty-one participants attended, 17 of whom were students from a variety of educational backgrounds, as detailed in Table 6. Appendix B4 shows the advertisement for Group 6.

Table 4: Overview of participants

Group	Description	n	Session attended	Session duration	Quiz(zes) completed
Group 1	Second-year Master of Audiology students	9	1	2 hours	A twice
Group 2	First-year Master of Audiology students	10	2	2 hours	B twice
Group 3	Novice participants	4	3	3 hours	C once
Group 4	Second-year Master of Audiology students	8	4	3 hours	C twice
Group 5	First-year Master of Audiology students	3	4	3 hours	C twice
Group 6	Novice participants	21	4	3 hours	C once

2.2.2.1 Token of appreciation

Participants who attended Sessions 1, 2 and 3 were given a $20 Westfield shopping voucher upon completing the session as a token of appreciation. Participants who attended Session 4 (which consisted of two 90-minute sessions) were given two $20 Westfield vouchers, one per session. The token was increased for Session 4 as only four participants had come to Session 3.

2.3 maskME software development

The maskME software was custom-written by Dr Robert Patuzzi (2005). In addition to allowing the user to practise obtaining pure-tone thresholds, maskME was designed to allow visual representation of masking concepts, such as crossover, cross-hearing, the occlusion effect, and the plateau curve. In this regard, maskME is unique among other computer-based simulators in audiology education. There is no limit to case numbers; new cases can easily be created to illustrate various hearing losses using a text file template.

maskME was designed to be used in a guided lesson alongside a workbook with activities corresponding to different cases in a structured lesson. It can also be used as a whole-class demonstration tool but was not designed to be given to users without any instruction.

The front panel of maskME (Figure 12) shows an audiogram for each ear. Masked thresholds are shown as solid lines. There are indicators to change the test ear, turn on a test tone, turn on masking noise, plot responses, turn on the occlusion effect, and change the interaural attenuation value, frequency, and case number. There are a series of boxes next to each audiogram which indicate which ear is hearing the tone and/or masking noise.

2.3.1.1 maskME front panel.

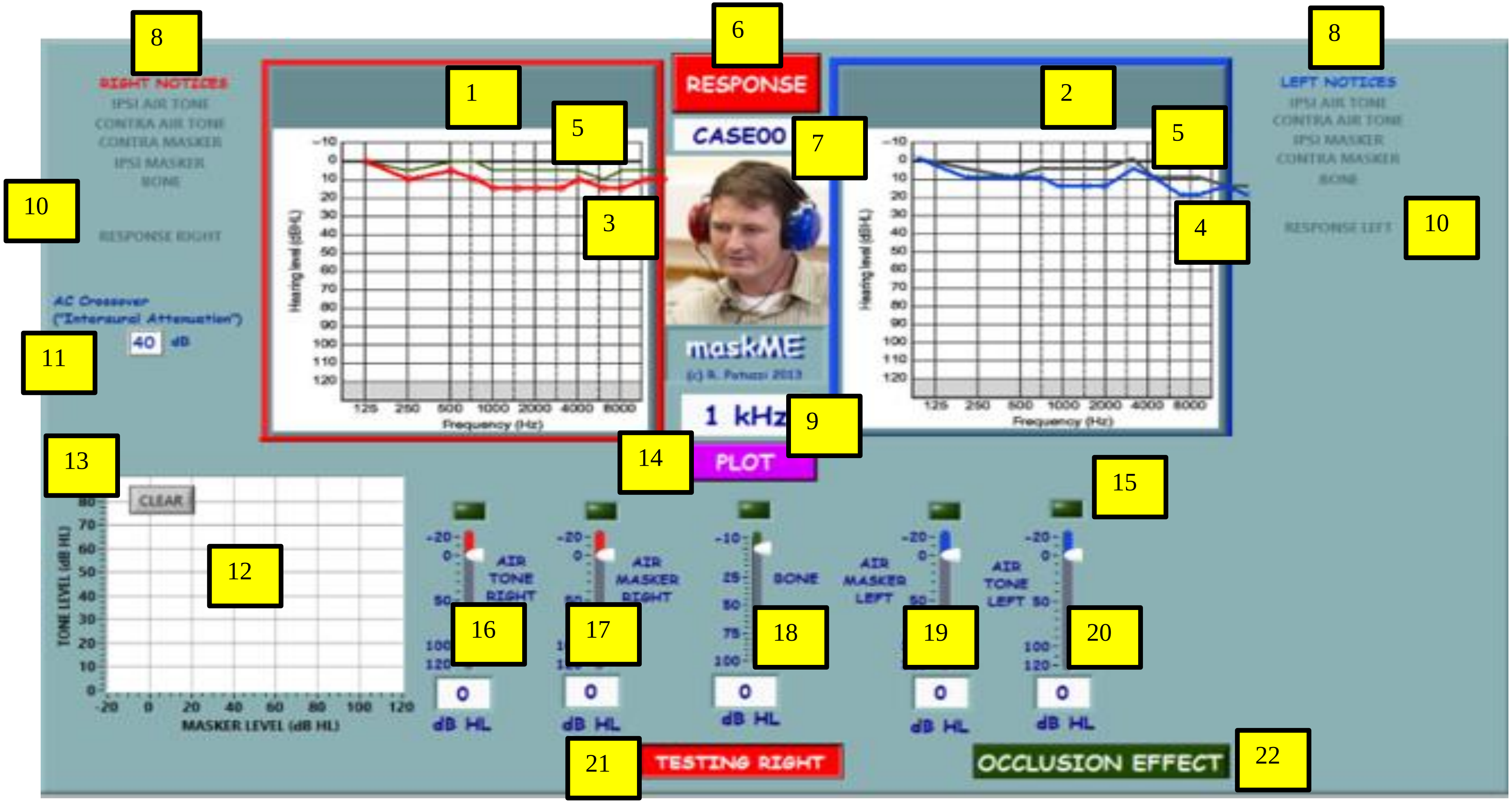


Figure 12: Screenshot of maskME's front panel. This is what the user sees when the programme is opened.

maskME front panel key (Figure 12)

1. Right ear audiogram
2. Left ear audiogram
3. The red line shows masked air-conduction thresholds for the right ear
4. The blue line shows masked air-conduction thresholds for the left ear
5. The solid black line shows masked bone-conduction thresholds
6. The RESPONSE button lights up orange when there is a response, and stays red for no response
7. Choose from 36 cases
8. Boxes light up when the ear detects the test signal or masker
9. Change frequency of test signal
10. RESPONSE RIGHT or RESPONSE LEFT indicate which ear is responding to the test signal
11. The interaural attenuation value can be changed by typing into this box
12. This chart can be used to plot the plateau curve using the PLOT button
13. The CLEAR button clears the chart
14. The Plot button creates marks on the chart to plot responses and non-responses to the test signal
15. Black buttons to turn on air conduction tones, bone conduction tones, or masking noise
16. Right ear air conduction tone level slider
17. Right ear masking noise level slider
18. Bone conduction tone level slider
19. Left ear air conduction tone level slider
20. Left ear masking noise level slider
21. Selects which ear to test
22. This button turns the occlusion effect on and improves bone conduction thresholds in the non-test ear.

maskME in use

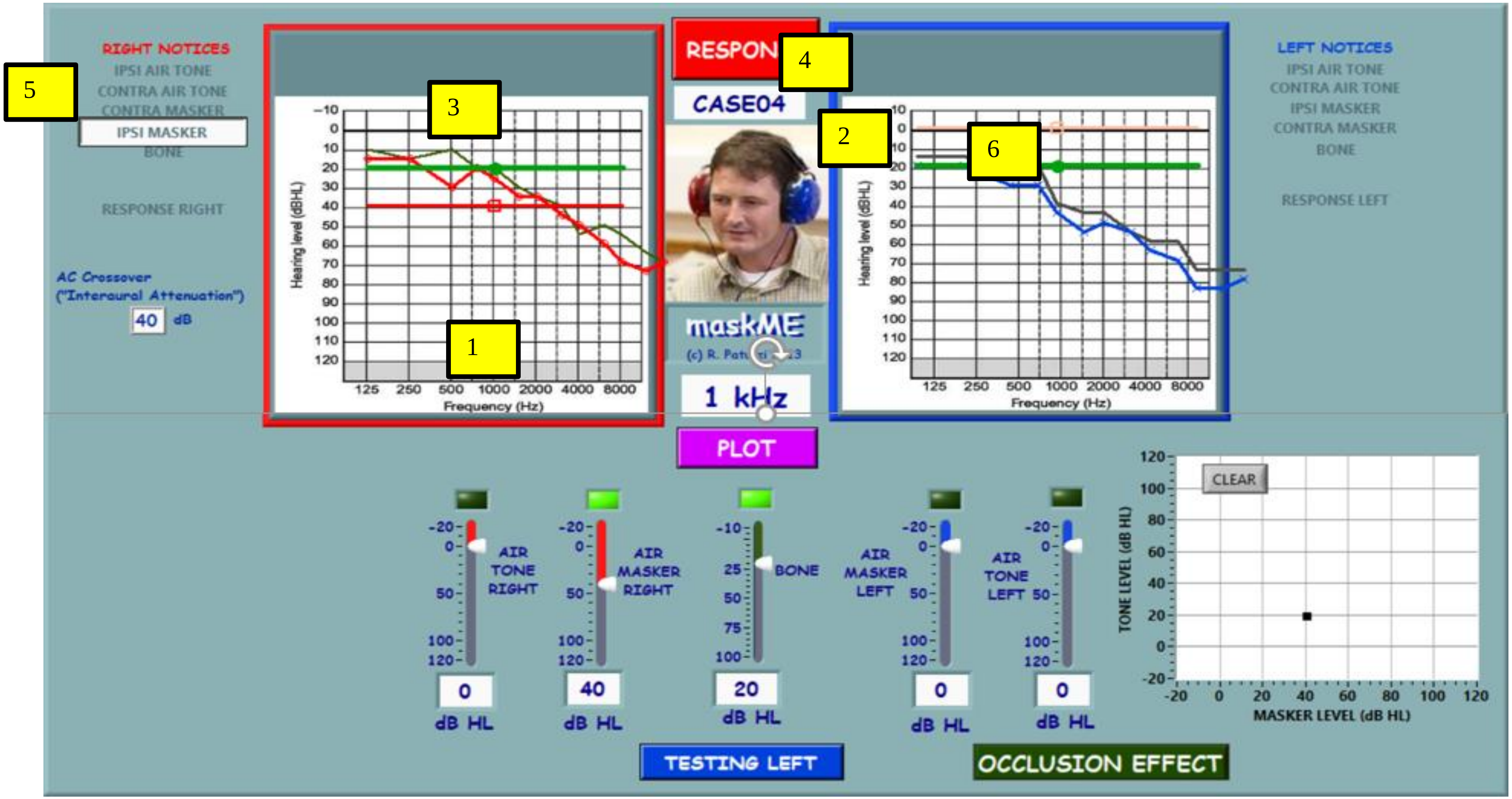


Figure 14: Screenshot of maskME in use. Case04 has a symmetrical, sloping hearing loss in both ears. The frequency of the test tone is 1 kHz and the left bone threshold is being tested at 20 dB with masking at 40 dB in the right ear. The plateau plotter has not been used in this example.

maskME in use key (Figure 13)

1. The BONE black box is green because it has been turned on to present a bone-conducted pure-tone signal to the left ear at 20dB.
   The AIR MASKER RIGHT black box is also green, indicating that it is presenting masking noise to the right ear at 40dB.
2. The green line shows the level of the bone conducted signal on the left ear's audiogram
3. The green line on the right ear's audiogram shows the level at which the bone conducted sound arrives in the right ear (at the same level as the test ear as interaural attenuation for bone conducted sounds is 0dB)
4. The peach line shows the level of crossover of the masking noise. The masking noise is presented at 40dB in the right ear, and because interaural attenuation is 40dB, the masking noise arrives at 0dB in the left ear.
5. The IPSI MASKER box has lit up for the right ear which tells the user that the right ear is hearing the masking noise going into the right ear
6. As the RESPONSE LEFT box has not lit up, this tells the user that the left ear has not detected the signal at 20dB with 40dB of masking noise in the right ear.

The plateau plotter chart

The plateau plotter is a key feature of maskME, allowing the user to create the plateau curve by plotting responses and non-responses to the test tone. As the tone and masker presentation levels are changed, the cursor moves on the chart. The user can plot a point (response or no response) for any combination of tone and masker level. Figure 14 shows an example of a completed plateau plotter chart. Only a subset of these points would be tested when performing masking. This plateau chart allows the user to see how the plateau is actually the boundary between chart areas of response and no response. Many of the activities in the workbooks required the use of the plateau plotter for the user to find out the true threshold of the test ear while masking.

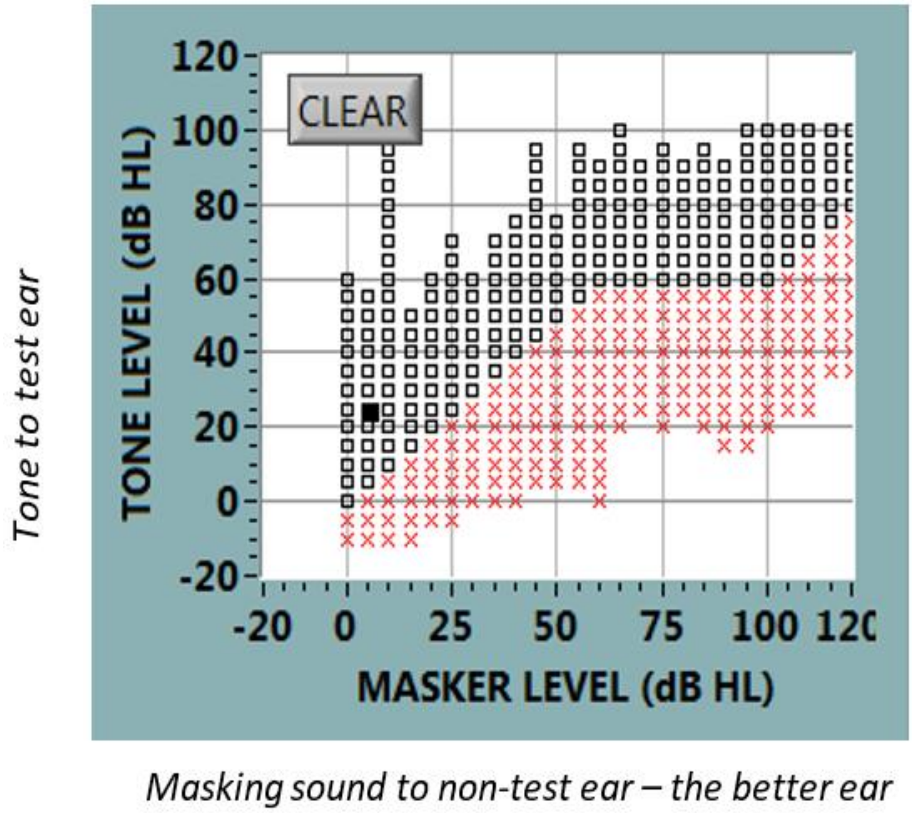


Figure 16: maskME plateau plotter showing the three stages of the plateau curve: undermasking, effective masking/the plateau (the horizontal part), and overmasking. The open black squares indicate a response from either ear to the test tone. The red crosses indicate no response to the test tone. The filled-in box is the user's current level of masking level and test tone presentation.

2.3.1.2 Software changes.

Several changes were made to software to fix errors, make it more user-friendly and to more clearly illustrate concepts. All changes were made before the first session and no changes were made between sessions. Several other changes were suggested but were not able to be completed. The changes made were:

- Enabling maskME to read up to 36 cases instead of just 15
- Ensuring that when *RESPONSE* lit up, so did the *RESPONSE* RIGHT or *RESPONSE* LEFT buttons (found below *RIGHT NOTICES* and *LEFT NOTICES)*
- Under the *RIGHT* or *LEFT NOTICES* box, the box labelled *CONTRA MASKER* was changing to *IPSI MARKER* when it was lighting up. This was changed so that the text would not change when the box lit up
- A new button was added for the user to plot the plateau curve, the *PLOT* button. Originally, the user had to click on the *RESPONSE* button to plot a point, but this was not intuitive
- When opened, maskME would already have some sliders turned on (e.g. playing a test tone). This was changed so that no tones or masking noise would be turned on when the user first opens the programme.

Figure 15 shows how some of the above changes looked in the front panel of maskME.

2.3.1.3 maskME front panel changes.

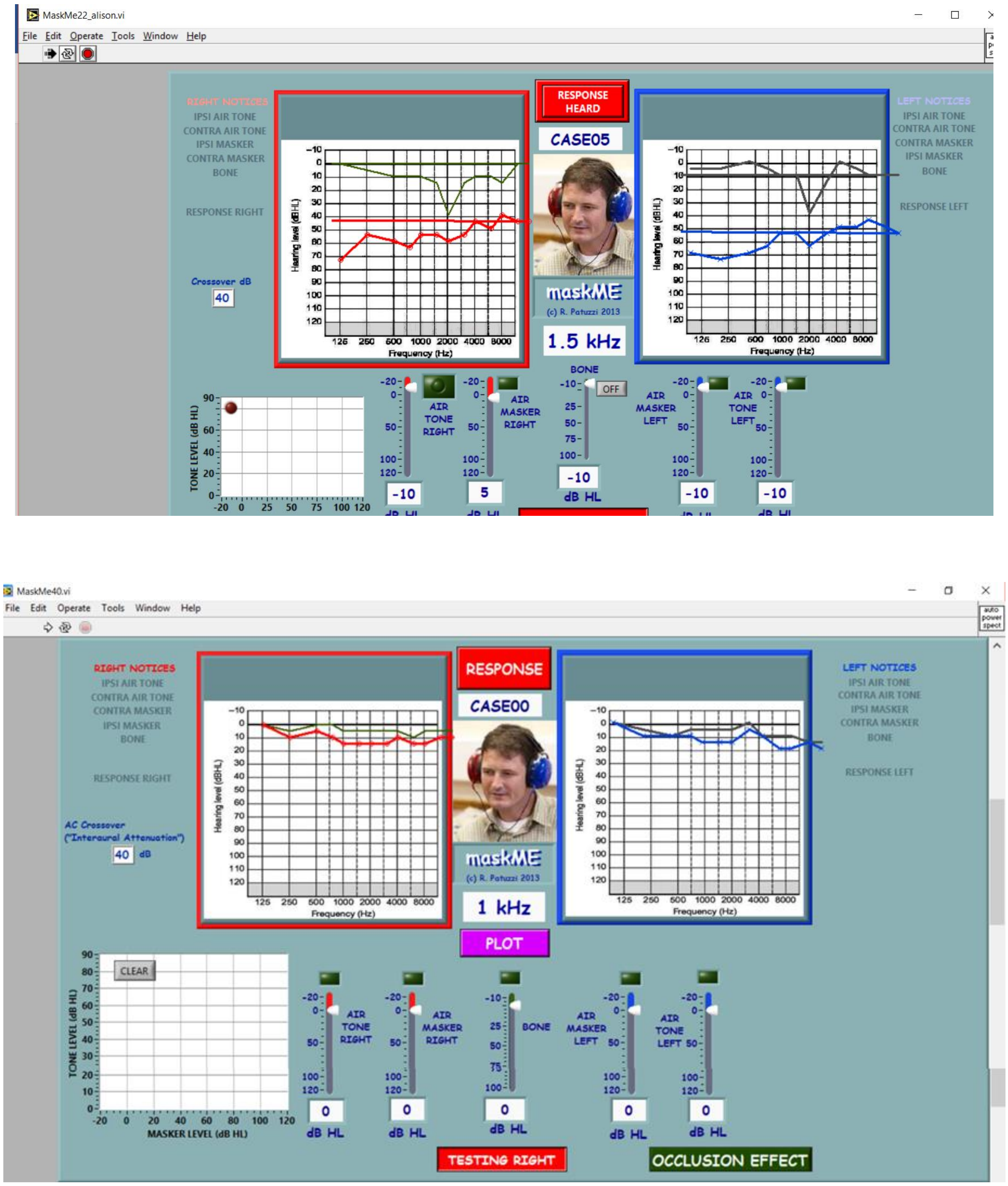


Figure 19: How maskME looked before (above) and after (below) changes were made. Note the differences in the Response button, Plot button, plateau plotter chart, black button size, and font colour for Right notices and Left notices.

2.3.1.4 Cases in maskME.

Thirty-six new cases were created in the present study to illustrate a variety of different hearing loss configurations that demonstrate specific concepts in masking. Some examples of the cases can be seen in Appendix D.

2.4 Learning outcomes development

Concepts to be included were chosen by reviewing masking lectures available online from universities around the world (Ozarks Technical Community College, 2014; The University of Canterbury, 2017; University of Florida, n.d. ; University of Kentucky, 2015; Utah State University, 2011) and by reviewing modern textbooks on audiology (Bess & Humes, 2008; Gelfand, 2016; Katz et al., 2015; Martin & Clark, 2015). The concepts chosen to be included in the present study's masking sessions were: interaural attenuation, crossover, cross-hearing, the purpose of masking, shadow curves, the occlusion effect, the plateau, undermasking, overmasking, masking dilemmas, and the effect of interaural attenuation, the occlusion effect and air-bone gaps on plateau width. Speech masking was also included in the first session but was later removed due to time constraints in the session. These key concepts were incorporated into the sessions in the PowerPoints, scripts, workbooks and quizzes. Tables in Appendix E detail which concepts were taught in each session, and which workbook and quiz questions addressed each concept.

2.5 Session structure development

The session was divided into several parts: Part 1, Part 2, the quiz and the questionnaire. The novice participants also received an additional part: an introduction to hearing and hearing testing. Iterative improvements to the content and presentation of the teaching slides, workbook, quiz and questionnaire were made throughout the study, guided by participant feedback and author observations.

Part 1 of the session introduced the concepts of: interaural attenuation, cross-hearing, crossover, shadow curves, air conduction and bone conduction. Part 1 was the same for all four sessions because there was little feedback about Part 1 from participants in the questionnaire. The same activities and examples were used for all groups because they were understood and answered well by participants.

Part 2 introduced the concepts of: doing masking using the Hood procedure, the plateau curve (undermasking, the plateau, and overmasking), the occlusion effect, and factors that affect plateau width (interaural attenuation, the occlusion effect, and air-bone gaps). In the first session, Part 2 also covered speech masking. Part 2 of the session changed more between sessions than Part 1 due to participant feedback and the author's own observations from the sessions, mainly concerning the time given to complete the plateau plotting activities in the workbooks (see Appendix G, pages 9-13 in Group 2's workbook).

Appendix F shows a breakdown for how much time was spent on different parts of each session. This information was used to refine future sessions, especially when particular parts of the session took longer than expected. For example, the quiz in Session 1 took participants much longer than anticipated, so more time was allowed for the quiz in subsequent sessions.

2.6 Workbook development

Five workbooks were developed for the four sessions (Appendix G)

Table 5: Workbooks used in each session.

Workbooks used in each session		
Name	***Session***	***Participants***
Workbook A	Session 1	Second-year audiology students
Workbook B	Session 2	First-year audiology students
Workbook C	Session 3	Novices
Workbook D	Session 4	Novices
Workbook E	Session 4	First- and second-year audiology students

Small changes were made between workbooks based on participant feedback and author observations. For example, Groups 1 and 2 had left feedback stating that they did not have enough time to complete all questions in Part 2. To address these concerns, several questions were removed and the questions were rearranged so that the most important ones would be completed first. More time was allocated to this part of the section, too. Some plateau plotting activities in Group 1's workbook were pen-and-paper based, instead of using maskME alone (e.g. question 9 in Workbook A). This was changed for the following groups due to participant feedback: students preferred using maskME for plotting plateaus than doing them by hand. Masking for speech testing was removed from the sessions after trialling this for Group 1. Additionally, the time allotted did not allow for speech masking to be adequately covered, so the focus was given to pure-tone masking in Sessions 2-4.

Audiometric jargon and abbreviations were simplified for novice groups. For example, the term *unmasked* and abbreviations such as *AC* for *air-conduction* had been used in the Workbooks A and B. These are familiar to audiology students but would add to the cognitive load for novice participants. Full terms and phrases were used in Workbooks C, D and E. More images were used in the Workbooks C, D and E, such as a chart with symbols used in audiograms and pictures of transducers (e.g. pages 3 and 4 of Workbook D).

More detail was given to the occlusion effect in Workbooks D and E as it was not well understood in previous sessions. An extra page was also added into Workbook C regarding the stages of the plateau (Appendix G, Workbook C, page 8) to help novices with this concept. After observing the first novice group experience difficulty with the steps of the Hood masking procedure (which is required for all Part 2 activities), an easy-to-follow diagram detailing the steps was created for Session 4 (see Appendix G, Workbook D, page 11).

The final addition to Workbooks D and E was a review of the intended learning outcomes. Every workbook's cover page had a list of the intended learning outcomes and the review page at the end was designed to remind the students of what the key takeaway points about masking were. The review page had simple sentences regarding the key concepts and required the participant to circle the correct answer or complete a sentence. Workbooks D and E were nearly identical, except for some activities in Part 1. New activities were introduced for Workbook E for the audiology students as many of these participants had already completed the activities in Workbook D in the first session of masking they attended.

2.7 PowerPoint development

The PowerPoint titled Masking A was used for Group 1, Masking B for Group 3, and Masking C for Groups 4, 5 and 6. The *Introduction to Hearing* PowerPoint was used for Groups 3 and 6. They can be found in Appendix H.

The masking PowerPoints became more detailed between sessions. Some participant feedback given for the question *What would you like to see changed in the session?* included:

*maybe a PowerPoint would be helpful to explain than just showing on maskME (*Group 2) and *more focussed on PowerPoint than workbook for theory – I find that easier to follow*

(Group 3). After Session 4 which had the more detailed Masking C PowerPoint, there were several positive comments about the PowerPoint, for example: *(the) PowerPoint use made it easier to understand, The slides were really good, information was well explained and organised* and *The PowerPoint was very useful and clear (for understanding cross-hearing) but the software is confusing and makes it harder*.

The *Introduction to Hearing* PowerPoint was used for novice participants Groups 3 and 6 to introduce them to hearing and hearing testing. It was based on Dr Greg O'Beirne's *Introduction to Hearing* PowerPoint that has been previously used for Speech and Language Therapy students at UC. It introduced: anatomy of the ear, a description of the hearing test procedure, air and bone conduction testing, transducers used, the occlusion effect, the audiogram and symbols used, and types of hearing loss.

2.8 Kahoots quizzes development

Two Kahoots quizzes (Kahoot, 2019) were used in Session 4 with all 36 participants and can be found in Appendices I1 and I2. They were intended to be a fun way of reviewing concepts as the session progressed. The *Introduction to Hearing* PowerPoint, addressed to the novices, was followed by a 17-question Kahoots quiz. All 32 participants, including the audiology students, played the quiz. After the *Masking C* PowerPoint, all participants played an 11-question Kahoots quiz on masking. Questions were chosen by the author and the answer to the question was displayed after everyone had answered it on their mobile phone or computer.

2.9 Quiz development

Three quizzes (Appendix J) were created to assess declarative knowledge of masking concepts. They were changed between sessions to address issues that arose, such as confusion over wording or time constraints. For example, Group 1 did not have enough time to finish Quiz A, so seven questions of the 20 were removed to ensure that future groups would be able to finish the assessment. The questions that were removed or changed were questions that assessed concepts covered by a remaining question.

2.9.1.1 Quiz A - Group 1.

The quiz for Group 1 had 20 questions including seven case-based questions. Participants were given 17 minutes to complete the pre-session quiz, and 15 minutes to complete the second. The post-session quiz was given 15 minutes before the session officially ended, but some students stayed longer and spent up to 25 minutes on the second quiz.

2.9.1.2 Quiz B - Group 2.

The quiz for Group 2 had nine questions with two case-based questions. It was reduced in size from the first quiz to account for time constraints. Seven questions from Quiz A were used in Quiz B. Participants were given 20 minutes to complete each quiz.

To ensure the duration of this quiz was appropriate, the author tested a shortened form of Quiz A with three second-year audiology students and asked them to time themselves completing it in test conditions. This prototype had 13 questions including four case-based questions. It took each student an average time of 22 minutes. The quiz was therefore shortened even further to comfortably fit within 20 minutes, so more questions were removed or rephrased until there were nine questions that covered the key concepts outlined in the learning outcomes.

2.9.1.3 Quiz C – Groups 3, 4, 5 and 6.

The quiz for Groups 3, 4, 5 and 6 had nine questions with two case-based questions. Participants were given 20 minutes to complete the quiz and questionnaire. Six of the nine questions were the same (or very similar) to questions in Quiz B.

The marking key for each quiz were checked by the study's supervisors and can be found in Appendix J.

2.10 Questionnaire development

The questionnaire was developed to answer Research Question 3: *Do participants perceive the masking session and maskME as useful for learning masking concepts?* (Appendix K). A paper-based questionnaire was chosen to collect this data instead of interviews or focus groups because completing them was quick, anonymous, and was able to be done during the session. Questions were chosen by analysing previous similar studies that asked for participant feedback after using a computer-based simulator in audiology education (Guard, 2013; Howland, 2012; Sanderson, 2012; William, 2013; Wilson et al., 2010). Other questions were chosen by reviewing the University of Canterbury Student Evaluation of Teaching questions which are used to obtain student feedback on lecturers (University of Canterbury, 2017).

The questionnaire consisted of eight five-point Likert scale statements and three questions for open-ended feedback. The Likert-scale statements were chosen to assess student perceptions of how well key concepts were addressed in the session. Participants were asked to circle *strongly agree, agree, neutral, disagree,* or *strongly disagree* to respond to each statement.

Questionnaire A was used for Groups 1 and 2. It was then modified to also collect demographic information from Group 3, with approval from the Educational Research

Human Ethics Committee (Questionnaire B). The questionnaire used for Group 4 and 5 was modified to ask one extra question for those who had also attended one of the first sessions on masking: *Since the session (17 August for second-year students and 27 August for first-year students), approximately how many masked audiograms have you done? To what extent do you think the masking session helped you with those masked audiograms?* This was Questionnaire C.

2.11 Rooms and recording

Three of the four sessions were run in a large, modern computer lab at the University of Canterbury. Session 2 was the only session run in a different room. The sessions were recorded so that the author could review her teaching for micro-teaching feedback. For example, if it had been the case that all participants in a particular session answered a quiz question incorrectly, it would be possible to review the recording and check what was taught. The time spent on activities was also checked using these recordings in order to assess whether a future session would require more or less time for the same activity. Participants were made aware in the consent forms that the sessions would be recorded.

2.12 Ethical approval

Ethical approval was gained from the University of Canterbury Educational Research Human Ethics Committee on the 22nd of June 2018, and amendments on the 6th of September 2018. Reference: 2018/25/ERHEC.

3 Results

Demographic data will first be presented, followed by results for each research question. Statistical tests were run in Version 25.0 of the IBM Statistical Package for the Social Sciences (SPSS). The distribution of quiz scores for each group was checked for normality using the Shapiro-Wilk test. Related samples t-tests were used to compare scores within the audiology student groups when the spread of data was normally distributed, and the Wilcoxon Signed Rank test when the data was not normally distributed. An independent t-test was used to compare quiz scores between novices and audiology student participants who attended Session 4.

3.1 Descriptive statistics

Demographic information is presented by group below and shows age, educational background and highest level of education currently achieved.

Table 6: Demographic data from Groups 1 and 2. Mean age is in years. S.D. = standard deviation.

Group 1 **Second-year audiology students (n=9)**		
	Age	**Highest level of education currently achieved**
	23	Bachelors
	23	Bachelors with Honours
	24	Bachelors with Honours
	27	Bachelors
	28	Bachelors
	27	Bachelors
	27	Bachelors with Honours
	24	Bachelors with Honours
	23	Bachelors with Honours
Mean age	**25.11**	
S.D.	**2.09**	

Group 2 **First-year audiology students (n=10)**		
	Age	**Highest level of education currently achieved**
	30	Postgraduate diploma
	22	Bachelors
	22	Bachelors
	24	Bachelors
	22	Bachelors
	24	Bachelors with Honours
	24	Bachelors with Honours
	22	Bachelors
	23	Bachelors
	38	Masters
Mean age	**25.10**	
S.D.	**5.13**	

Table 7: Demographic data from Groups 3, 4 and 5. DNA = did not answer.

Group 3 Novice participants (n=4)			
	Age	**If currently a student, degree studying towards**	**Highest level of education currently achieved**
	18	Bachelor of Engineering	NCEA Level 3
	26	Master of Financial Management	DNA
	30	n/a	Masters
	32	PhD (History)	DNA
Mean age	26.5		
S.D.	6.19		

Group 4 Second-year audiology students (n=8)		
	Age	**Highest level of education currently achieved**
	26	Bachelors
	27	Bachelors
	23	Bachelors with Honours
	23	Bachelors with Honours
	23	Bachelors
	28	Bachelors
	27	Bachelors
	28	Masters
Mean age	**25.63**	
S.D.	**2.26**	

Group 5 First-year audiology students (n=3)		
	Age	**Highest level of education currently achieved**
	30	Bachelors
	39	PhD
	24	Honours
Mean age	**31.00**	
S.D.	**7.55**	

Table 8: Demographic data from Group 6. DNA = did not answer.

Group 6 Novice participants (n=21)			
	Age	**If currently a student, degree studying towards**	**Highest level of education currently achieved**
	26	Master of Applied Data Science	Masters
	23	Master of Applied Data Science	Bachelors
	27	Post Graduate IST	Bachelors
	49	PhD (Environmental Science)	Masters
	24	n/a	NCEA Level 3
	19	Bachelor of Science (Computer Science)	NCEA Level 3
	29	PhD (Microbiology)	Masters
	24	Master in Engineering Geology	Masters
	33	PhD (Philosophy)	PhD
	42	n/a	Bachelors
	20	Bachelor of Accounting and Financing	DNA
	25	PhD	Masters
	23	Post Graduate Diploma (Ecology)	Bachelors
	18	Bachelor of Engineering (Software)	IB Diploma
	29	PhD (Psychology)	Masters
	42	Bachelor of Medical Imagining	Post-graduate diploma
	28	n/a	Masters
	30	PhD (Social Science)	Masters
	19	Bachelor of Arts (Journalism)	NCEA Level 3
	18	Bachelor of Commerce	NCEA Level 3
	30	PhD	PhD
Mean age	**27.52**		
S.D.	**8.32**		

3.2 Research question 1

For audiology students, does knowledge of the concepts of masking improve after a session on masking with maskME?

Participants completed two quizzes in each session that they attended in order to assess the effect of the session on their declarative knowledge of masking. For the purpose of comparison, data will be presented first from the second-year audiology students (Groups 1 and 4), followed by data from the first-year audiology students (Groups 2 and 5).

Quiz scores indicate that audiology students' declarative knowledge of masking concepts did improve after a session on masking with maskME. Groups 1 and 2 both had statistically significantly higher post-session quiz scores (see Figures 16 and 19). Groups 4 and 5 also had higher post-session quiz scores, but not significantly so (see Figures 17 and 20).

3.2.1 Second-year audiology students.

There were two groups of second-year audiology students: Group 1 and Group 4.

Group 1 attended Session 1 and consisted of a group of nine second-year audiology students, the author's peers. Group 4 attended Session 4 and consisted of eight students. Group 4 was made up of seven of the nine participants who came to Session 1, and one other who had not come to Session 1.

Group 1 completed Quiz A twice during Session 1 and Group 4 completed Quiz C twice during Session 4. Because the quizzes were different, results between sessions will not be compared.

3.2.1.1 Session 1 - Group 1 (n=9 second-year audiology students).

The mean score for the pre-session quiz was 51.75±0.19% and the mean score for the post-session quiz was 60.23±0.22%. Seven of the nine participants had increased post-session quiz scores. Figure 16 demonstrates a trend of improved post-session quiz scores, with one participant maintaining the same score in both pre- and post-session quiz, and one participant scoring worse on the post-session quiz. All other participants had increased scores in the post-session quiz. The mean improvement in score at the post-session quiz was 11.79±0.16%. The box plot in Figure 16 is demonstrative of the positive shift in mean quiz scores.

The Shapiro-Wilk test for normality determined that both pre-session and post-session scores of Group 1 for Quiz A were not significantly different from a normal distribution, therefore parametric tests could be used. A one-tailed, related-samples t-test was used as it was hypothesised that the post-session quiz scores would be significantly higher than the pre-session scores. As hypothesised, Group 1's post-session Quiz A scores (M = 60.23%, SD = 0.21), were significantly higher than their pre-session Quiz A scores (M = 51.75%, SD = 0.18), $t(8) = 2.20$, $p = .0297$.

Quiz A was the longest of the three quizzes and several students did not have enough time to complete it, which could have negatively influenced the scores. Participants were given 17-20 minutes to complete each quiz, as detailed in the Methods section.

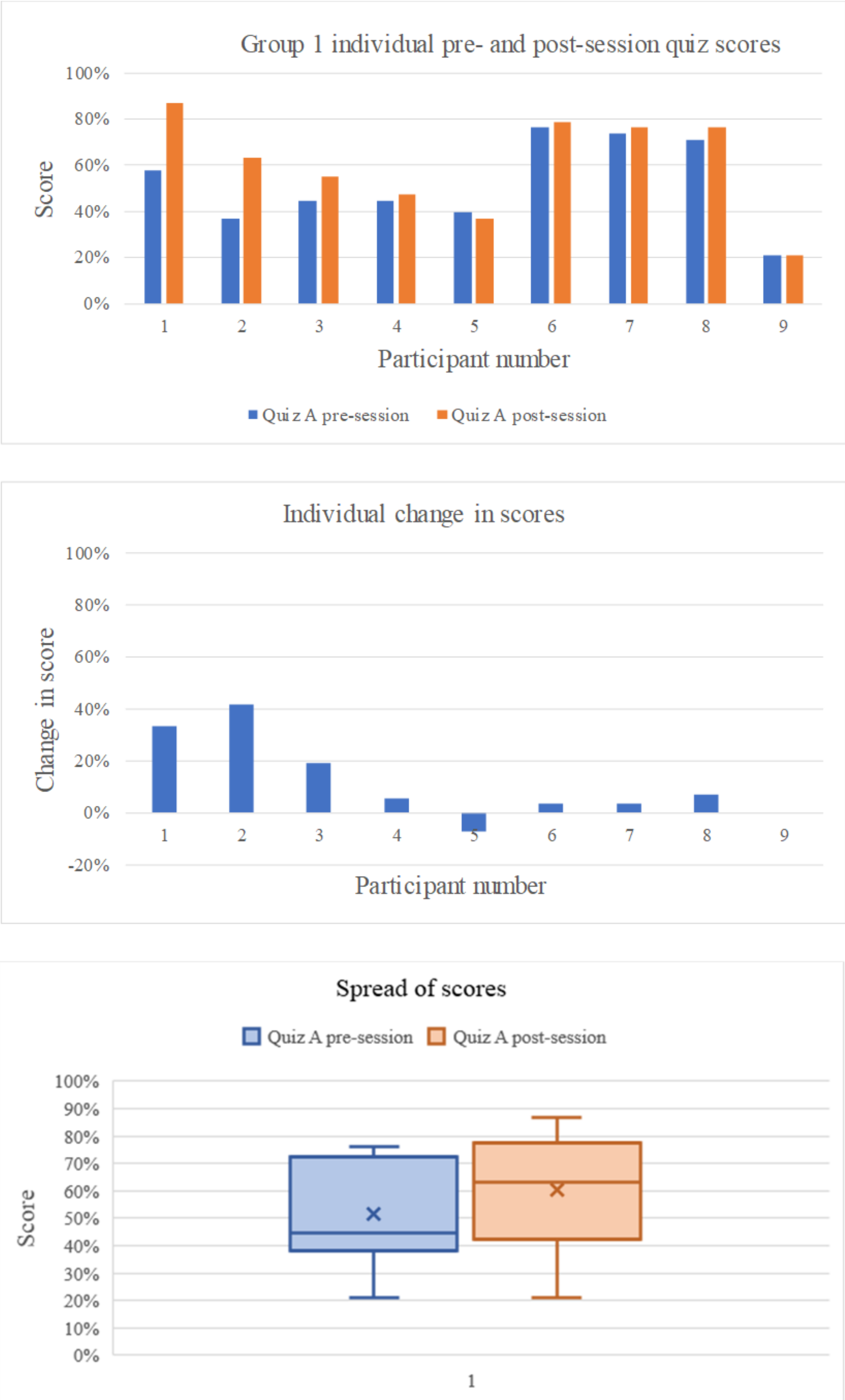


Figure 20: Group 1 (second-year audiology students). Quiz A pre- and post-session scores. In general, higher post-session scores can be seen in each graph. Individual pre- and post-session scores can be seen in the first graph, and the change in scores can be seen in the second graph. Only Participants 5 an 9 did not improve their scores at the post-session quiz. The Spread of Scores *graph shows the distribution of scores and how the mean score for each quiz changed after the session.*

3.2.1.2 Session 4 - Group 4 (n=8 second-year audiology students).

The mean score for the pre-session quiz was 84.38±0.11% and the mean score for the post-session quiz was 91.67±0.06%. There was less improvement in quiz scores in this group compared to the first group of second-year students. According to the Shapiro-Wilk test for normality, the post-session Quiz C scores were normally distributed but the pre-session Quiz C scores were not. Therefore, the Wilcoxon Signed Rank test was used and indicated that there were no significant differences between Quiz C pre-session score (Mdn = 91.67%) than in Quiz C post-session scores (Mdn = 91.67%), Z = -1.10, $p < .273$.

The mean improvement in scores from the pre-session to the post-session quiz was 7.95±0.15%. As can be seen in Figure 17, one student's post-session quiz score was worse than the pre-session score and four participants' scores did not change. All other participants had improved post-session quiz scores. Two participants had increases in score in the post-session quiz of over 27%.

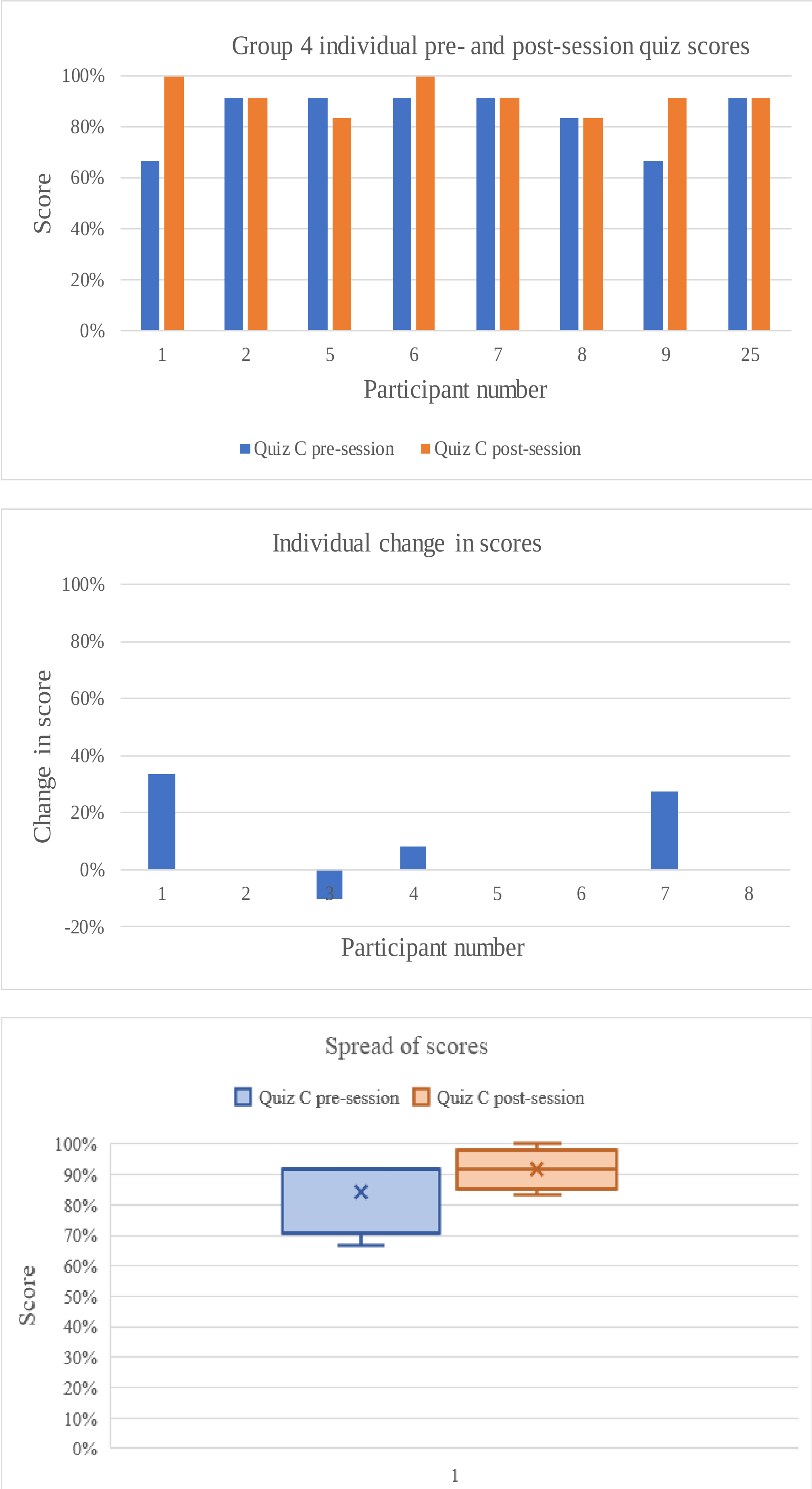


Figure 21: Group 4's (second-year audiology students) pre- and post-session scores for Quiz C. Improved scores at the post-session quiz measure can be seen, particularly in the Spread of Scores *graph. The* Change in Scores *graph shows that fewer participants had increased scores than Group 1, where 7 of the 9 participants had increased scores.*

3.2.1.3 Second-year audiology students who attended two sessions.

Seven second-year audiology students attended both Session 1 and Session 4. Although there is a trend for mean scores to increase between each quiz, as seen in Table 10, Quiz A and C were different and several participants did not finish Quiz A in the time allocated whereas Quiz C was completed by all participants in the time given.

For completeness, Figure 18 shows quiz scores by participant, demonstrating that all second-year audiology students who attended both sessions showed some increase in quiz score after attending a session when compared to the pre-session quiz score. The mean increase in scores between the pre- and post-session Quiz A was 18.46±29.84%, while the mean increase between the pre- and post-session Quiz C was 12.5±22.28%.

Two participants had the same scores (91.67%) for both the pre- and post-session Quiz C in Session 4 (Participants 6 and 8) indicating a possible ceiling effect. Overall, there is a trend of quiz scores improving over time for all seven audiology student participants who attended both sessions.

Table 9: Mean quiz scores for second year audiology students who attended two sessions.

Year 2 audiology students who attended Sessions 1 and 4 (n=7)				
	Quiz A pre-session	**Quiz A post-session**	**Quiz C pre-session**	**Quiz C post-session**
Mean score	53.76%	62.78%	83.33%	91.67%
S.D.	21.53	24.57	11.79	6.8

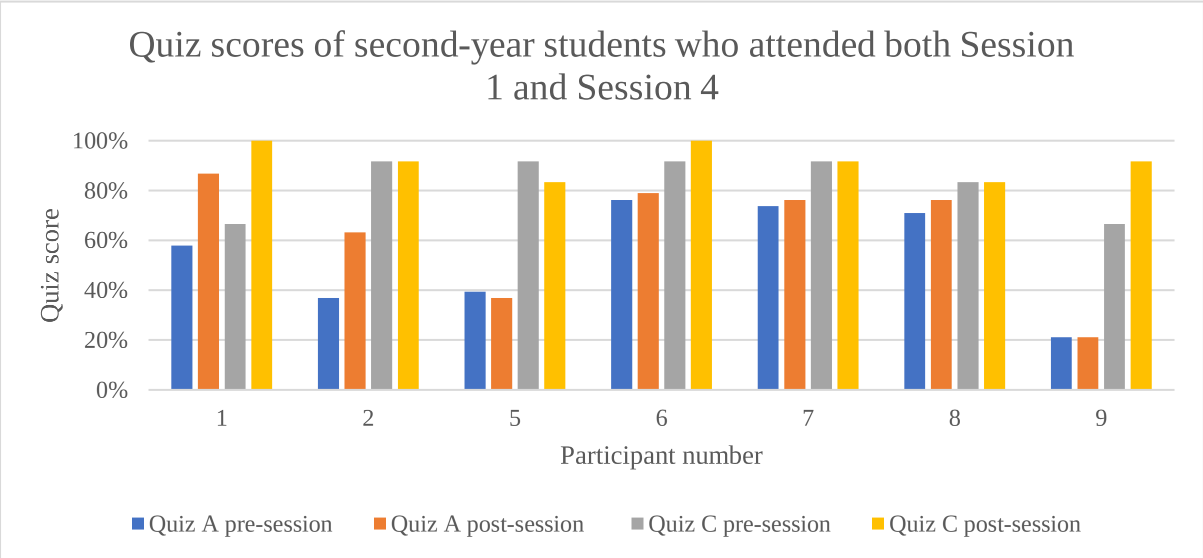


Figure 22: Individual participant quiz scores for common second-year audiology student participants across Sessions 1 and 4. As Quiz A and C were different, no comparisons may be made with individuals.

3.2.1.4 Summary of results for second-year audiology students.

For second-year audiology students, attending a session on masking with maskME had a positive effect on their declarative knowledge of masking concepts. For Group 1, there was a significant increase at the post-session quiz after Session 1. For Group 4, there was an increase in the post-session quiz after Session 4, although it was not statistically significant.

Because Quiz A and C were different quizzes, generalisations cannot be made regarding how a second session on masking affected quiz scores for participants who attended both sessions. Quiz A and C covered the same concepts, but different wording and examples were used.

More students' scores in the post-session measure increased in Group 1 than in Group 4. In Group 1, seven of the nine students had improved scores in the post-session quiz. One participant's scores did not change and one participant's scores worsened by 7.14%. In Group 4, three of the eight students had improved scores in the post-session quiz, four participants' scores did not change between quizzes, and one participant's score worsened by 10%.

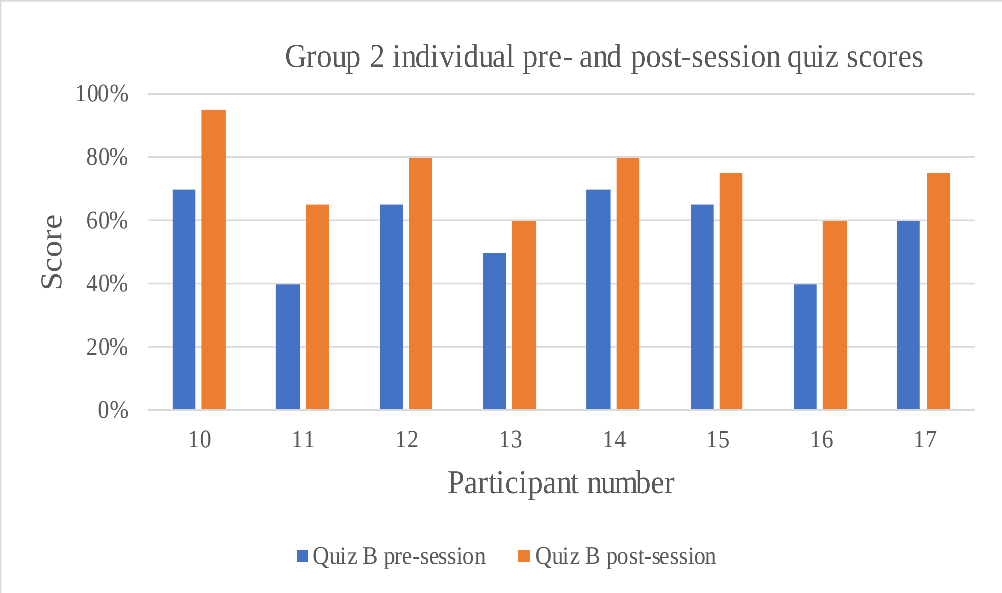
3.2.2 First-year audiology students.

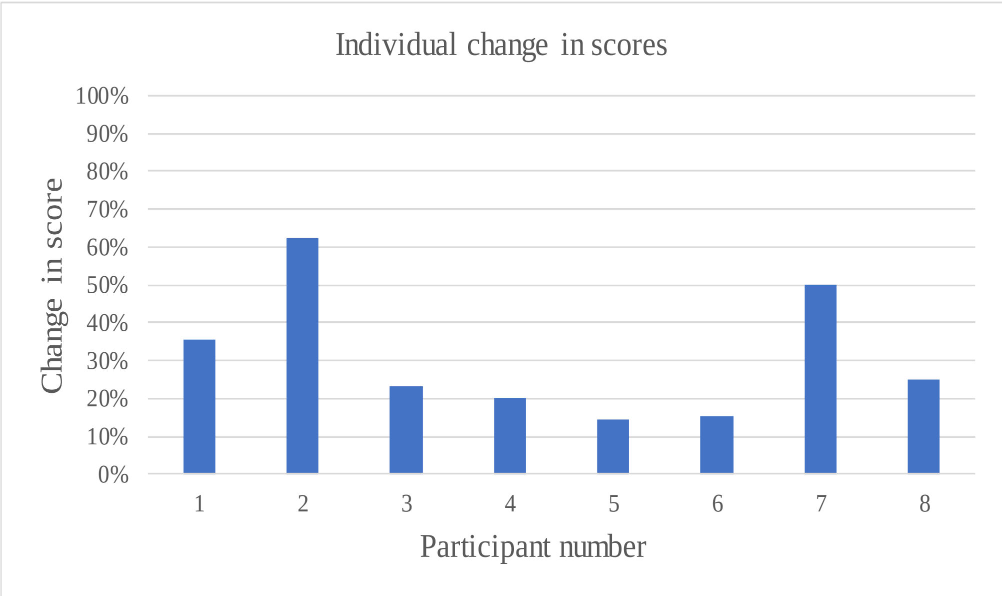
Session 2 was attended ten first-year audiology students: Group 2. Session 4 was attended by three first-year audiology students: Group 5. Only one student from this class attended both sessions. Group 2 completed Quiz B twice during Session 2 and Group 5 completed Quiz C twice during Session 4.

3.2.2.1 Session 2 - Group 2 (n=10 first-year audiology students).

All students in Group 2 had improved scores on the post-session quiz than in the pre-session, as shown in Figure 19. The Shapiro-Wilk test for normality showed that both pre-session and post-session scores of Group 2 for Quiz B were not significantly different from a normal distribution, meaning that parametric tests could be used. A one-tailed, related-samples t-test was used. Group 2’s post-session Quiz B scores (M = 73.5%, SD = 0.12) were significantly higher than their pre-session Quiz B scores (M = 56.5%, SD = 0.11), $t(9) = 5.85$, $p = .0001$.

The mean improvement in scores between pre-session Quiz B and post-session Quiz B was 32.51±0.21%. Participants 11, 16 and 19 each improved their post-session quiz scores by 50% or more. Unlike Quiz A, Quiz B was completed by all participants in the given time.





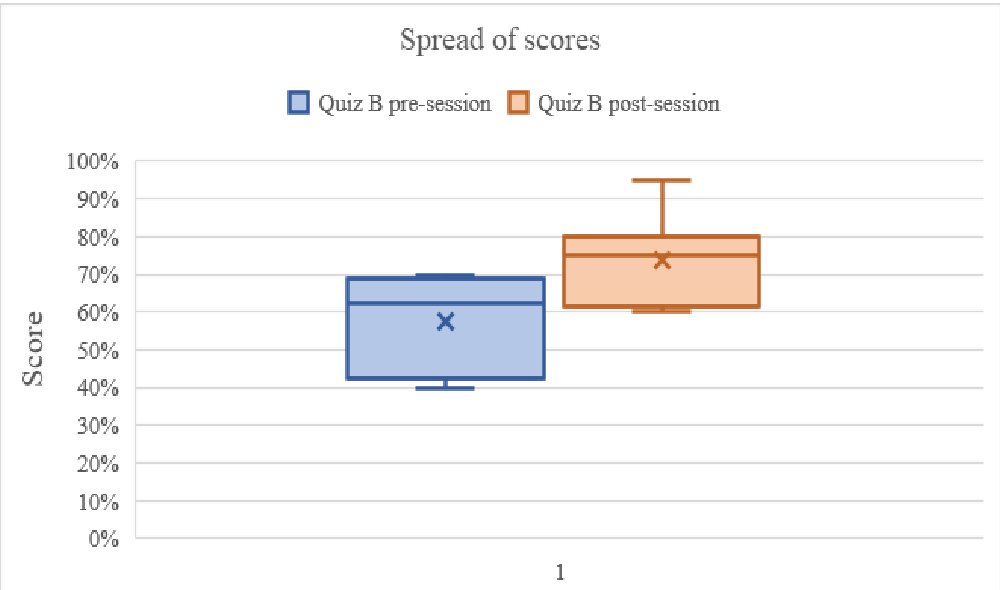


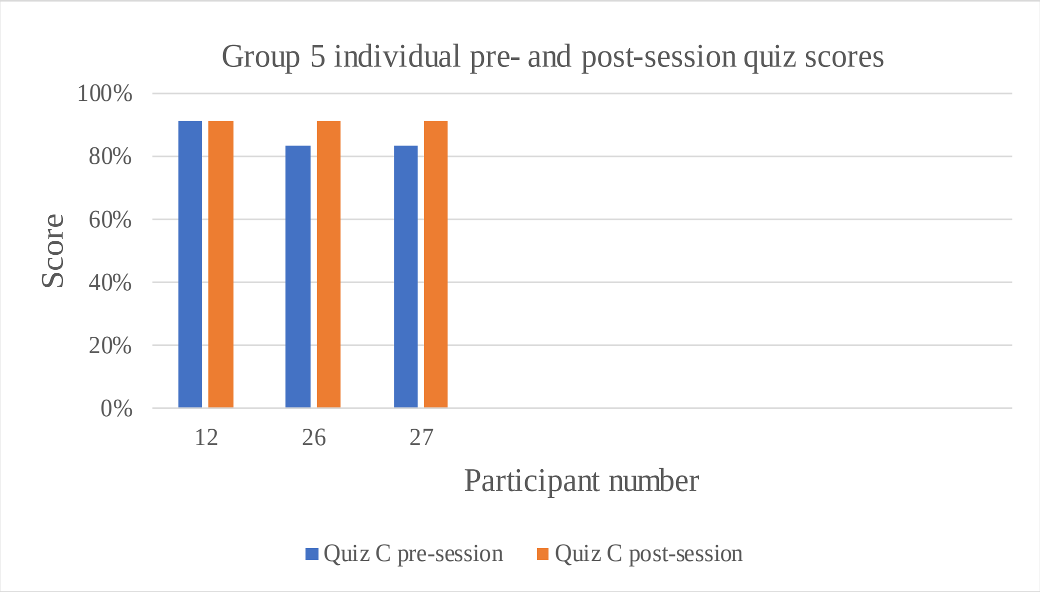
Figure 23: Group 2 (first-year audiology students). Quiz B pre- and post-session scores. All participants had improved scores in the post-session quiz and the change in mean score can clearly be seen in the Spread of Scores graph.

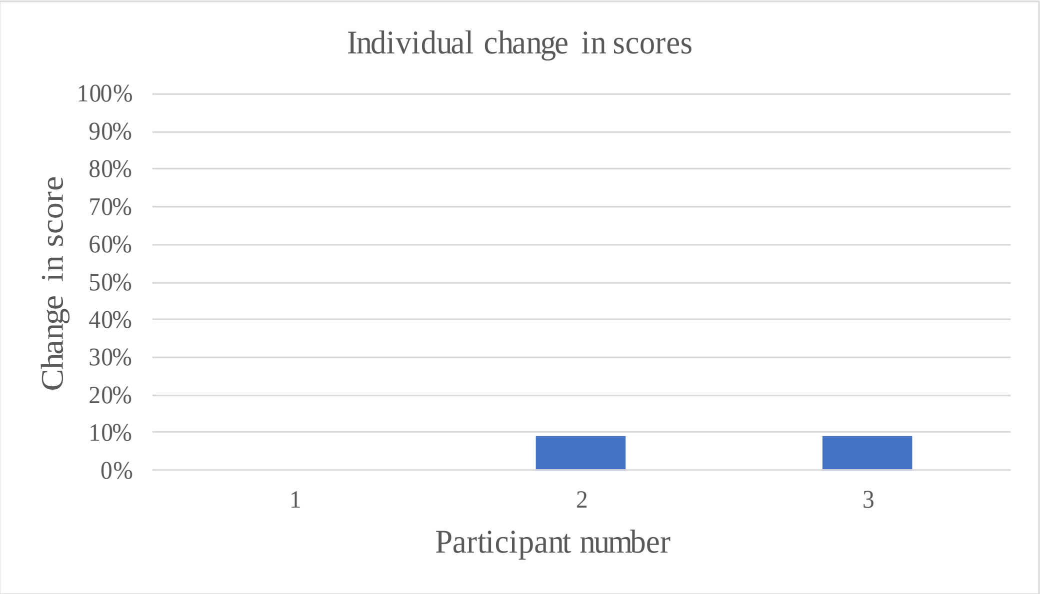
3.2.2.2 Session 4 - Group 5 (n=3 first-year audiology students).

Using the Shapiro-Wilk test for normality, neither pre-session Quiz C scores nor post-session Quiz C scores were normally distributed. Therefore, the Wilcoxon Signed Rank test was used as an alternative to the related sample t-test. The Wilcoxon Signed-ranks test indicated that there were no significant differences between Quiz C pre-session score (Mdn = 83%) than in Quiz C post-session scores (Mdn = 91.67%), Z = -1.41, $p < .157$.

Participant 12's scores did not change between the two quizzes administered in Session 4, and the other two participants' scores increased by 9.09% (i.e. one mark in the quiz). Participant 12 was the one participant who also attended Session 2. The mean improvement in quiz scores was 6.06±0.05%, as seen in Figure 20.

Because participant numbers were limited to three, no concrete statistical conclusions can be drawn from this data.





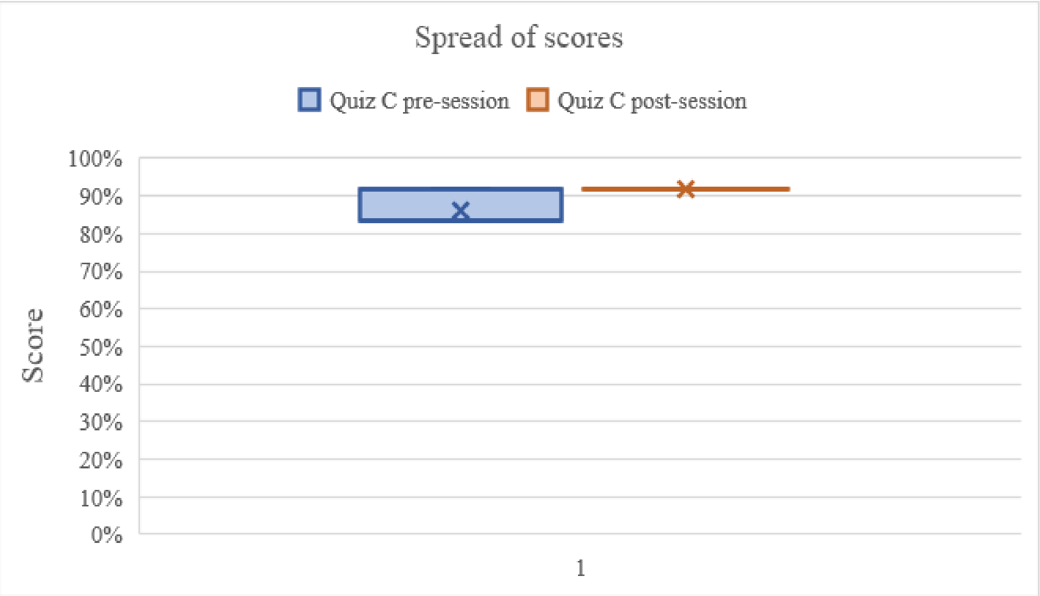


Figure 24: Group 5 (first-year audiology students). Quiz C pre- and post-session scores. Two of the three participants scored one mark higher in the post-session quiz, as seen in the Change in *Scores graph. The small number of participants in this group make it difficult to draw conclusions about this population.*

3.2.2.3 First-year audiology students who attended two sessions.

Only one first-year audiology student, Participant 12, attended two sessions. For completeness, that participant's results are displayed below in Table 10. The individual's scores increased by 23.08% between the pre-session and post-session Quiz B. However, the score did not increase between the pre-session and post-session Quiz C, indicating a possible ceiling effect.

Table 10: Quiz scores for the first-year audiology student who attended two sessions.

Year 1 audiology student who attended both Session 2 and Session 4				
Participant number	Quiz B pre-session	Quiz B post-session	Quiz C pre-session	Quiz C post-session
12	54.17%	66.67%	91.67%	91.67%

3.2.2.4 Summary of results for first-year audiology students.

Like with their second-year audiology student peers, the first-year audiology students' results indicated that attending a session on masking with maskME had a positive effect on their declarative knowledge of masking concepts. This was more evident in Group 2, whose quiz scores increased significantly between the pre- and post-session measures, with the mean improvement being 32.51±0.21%. For Group 4, quiz scores improved at the post-session quiz, but were not statistically significant.

3.2.3 Participants that attended two sessions.

Audiology students who attended two sessions had an additional question in their questionnaire at the end of Session 4: *if you attended the first masking session, to what extent do you think the masking session helped you with masked audiograms (in practice)?* Six of the seven second-year students answered this, and one of the first-year students. Their responses are shown in Table 11. Two of the second-year students and the first-year student agreed that the session had been useful for their clinical practise, and four responded *neutral*. Because so few participants were able to answer this question, the responses cannot be used to make generalisations about how useful the sessions are for practical masking work. The sessions focus on the underlying concepts of masking rather than the practical procedures involved.

Table 11: Audiology students who attended two sessions responded to a question about the usefulness of attending the first session on masking in practice.

Participant ratings of session usefulness in practice					
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Year 2 audiology students (n=6)	0	2	4	0	0
Year 1 audiology students (n=1)	0	1	0	0	0

3.2.4 Summary of Research Question 1.

Each group of audiology students completed a pre-session and post-session quiz and improvements in the post-session quiz scores were seen in every group.

Statistical testing revealed that Groups 1 and 2 both had significantly higher quiz scores at the post-session quiz than in the pre-session quiz of the session they attended. Groups 4 and 5 also had (non-statistically-significant) higher scores at the post-session quiz compared to the pre-session quiz.

Both year levels of students had greater improvements in the mean scores of the quizzes in the first session attended compared to the second session. This could be due to several reasons, such as participants' knowledge of masking solidifying over time, a ceiling effect, the effect of the first session (for those participants who attended two sessions), or Quiz C being easier than Quiz A or B.

3.3 Research question 2

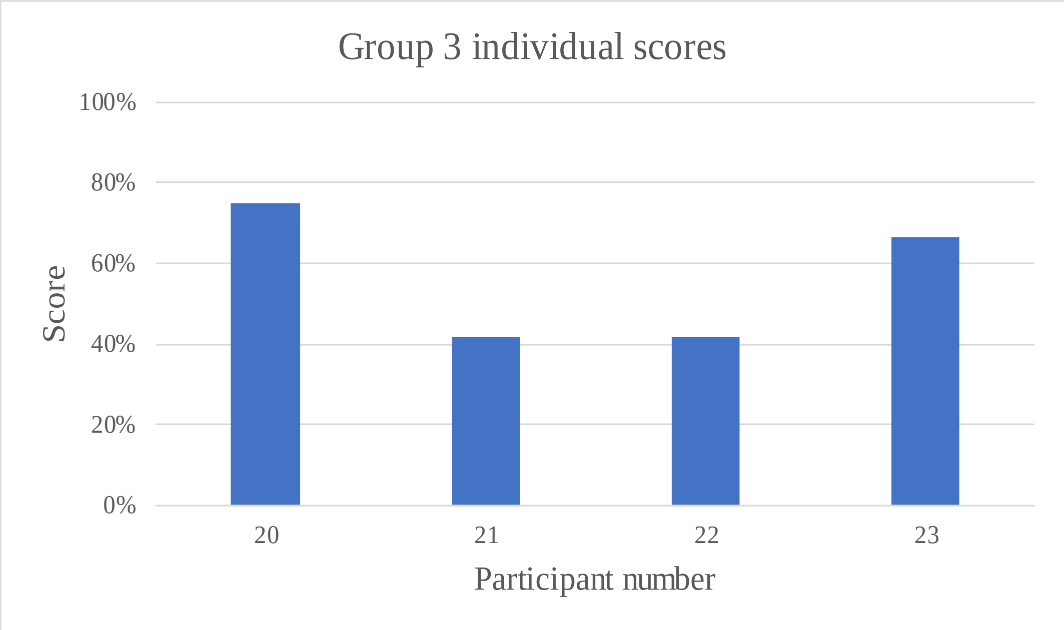
How does a group of novice participants perform on a masking quiz following a session on hearing and masking?

This was answered by administering a paper-based quiz to these participants and comparing their results to those of the audiology student participants. Two sessions were run that recruited novice participants: Session 3 with Group 3 (n=4), and Session 4 with Group 6 (n=21). Groups 3 and 6 completed the same quiz (Quiz C) but received slightly different interventions: Session 3 and Session 4 respectively.

Because Session 4 was also attended by audiology students (Groups 4 and 5), Quiz C scores between the novices and audiology students can be compared. It was found that the audiology student group had statistically significantly higher quiz scores than the novices (Figure 22).

3.3.1 Session 3 - Group 3 (n=4 novices).

Group 3 consisted of four participants who were not audiology students. They had backgrounds in engineering, financial management and history (see: Table 8) and no knowledge of hearing or masking. The mean score for Group 3 on Quiz C was 56.25±0.17%. Two participants achieved scores of 66.67% or higher, and two participants scored 41.67%, shown in Figure 21. Because there were only four participants in this group, generalisations about the novices' understanding of masking concepts after one session cannot be made. Also, unlike Group 6, no audiology student participants were invited to Group 3's session, so there are no quiz scores that can be directly compared between audiology students and novices. However, this session was useful in preparing for Session 4, which 21 novice participants attended.



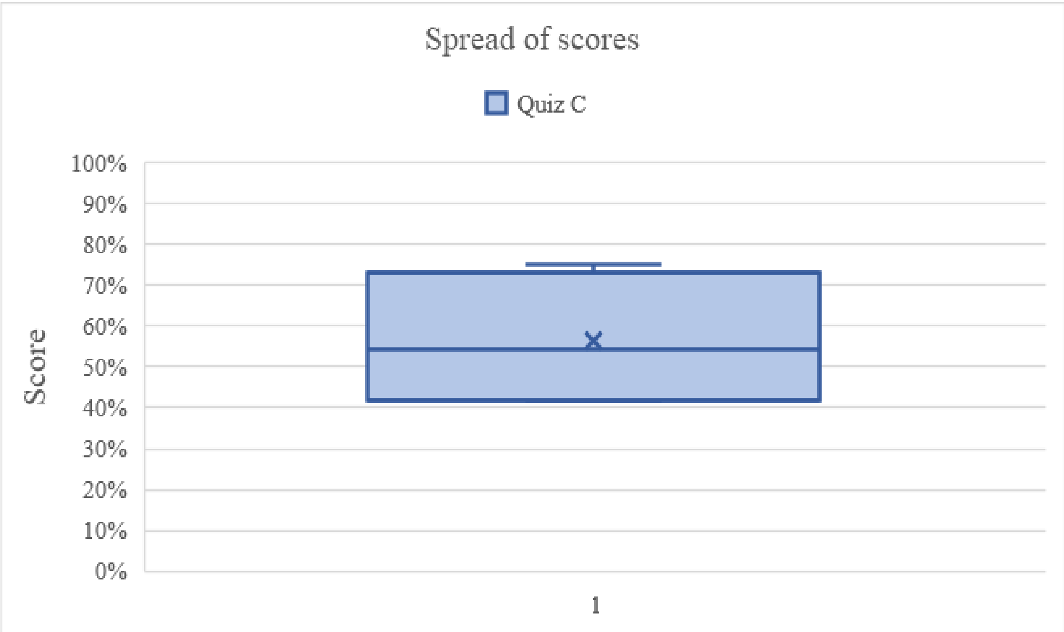


Figure 25: Group 3 (novice participants). Quiz C scores after a three-hour session on hearing and masking. The mean score for Group 3 on Quiz C was 56.25±0.17%.

3.3.2 Session 4 - Group 6 (n=21 novices) and audiology students (n=11).

Twenty-one participants made up Group 6, who attended Session 4 along with Groups 4 and 5 (audiology students). They came from a variety of educational backgrounds, as detailed in Tables 8 and 9.

Both years of audiology students who attended Session 4 were combined into one group and their quiz results were compared against the novice group. The audiology students' (n=11) mean score of the post-session Quiz C was 91.67±5%. Their mean score at the pre-session Quiz C was 84.85±9%. Group 6's mean quiz score was 48.02±16.01%. There were three outliers in Group 6: two with high scores (75% and 83.33%) and one with the low score of 16.67%. Figure 22 shows individual quiz scores and the spread of scores for both groups.

Quiz C scores for Group 6 were normally distributed, according to the Shapiro-Wilk test but the combined group of audiology students' Quiz C scores were not normally distributed. However, upon visual inspection of the histogram, the centre of the data was observed to have a high density and the outer tails both had lower density. Therefore, it was decided to use an independent samples t-test to compare scores between audiology students and novice participants.

Quiz C scores for audiology students (M = 91.67%, SD = 0.05) were significantly higher than the novice participants Quiz C scores (M = 48.02%, SD = 0.16), $t(27.11) = 11.42$, $p = \ <0.001$

Figure 26: Quiz C scores for the audiology students and novices who attended Session 4. The first and second year audiology students were combined into one group. Their scores were significantly higher than the novices' scores, and also had less variability, as can be seen in the box plots.

3.3.3 Summary of Research Question 2.

Research question two aimed to discover how novice participants would score on a quiz on masking after a one-off, three-hour session on hearing and masking. Overall, results from the two groups of novice participants indicate that this population do not perform as well as audiology students when given the same intervention and assessment.

The first group of novice participants (Group 3) consisted of four people who completed Quiz C. Their mean score on the quiz was 56.25±0.17%. The second group (Group 6) of novice participants consisted of 21 people who also completed Quiz C. Their mean score was 48.02±16.01%, lower than Group 3's.

Audiology students also attended the same session as Group 6 and had significantly higher quiz score results in their post-session quizzes, with a mean score of 91.67±0.05%.

Interestingly, two participants from Group 6 scored higher than some audiology students. Novice Participants 32 and 34 scored 75% and 83.33% respectively in Quiz C. In the pre-session Quiz C, one second-year audiology student scored 66.37%, and in the post-session Quiz C, two second-year audiology students also scored 83.33%.

3.4 Research question 3

Do participants perceive the masking session and maskME as useful for learning masking concepts?

This was answered by analysing answers from paper questionnaires which were given to participants at the end of each session. There were eight five-point Likert-scale statements, and three questions for open ended feedback on aspects of the session they enjoyed, changes they would like to see, and anything else they thought the researcher should know. Participants provided detailed feedback to the open-ended questions, giving an in-depth insight into the experience of the sessions.

Likert-scale data was coded for analysis: *strongly agree* = 5, *agree* = 4, *neutral* = 3, *disagree* = 2, *strongly disagree* = 1.

All sessions had average responses lying between *agree* and *strongly agree*, indicating a more positive than negative experience with the session. For all statements together, the mean score for Session 1 was 4.29±0.25, Session 2 was 4.15±0.22, Session 3 was 4.16±0.32, and Session 4 was 4.16±0.13.

Because there were four sessions in total which were organised slightly differently, responses to the questionnaires will be presented by session. This will be followed by samples of the open-ended feedback from each session. Full transcripts of this feedback are attached as Appendix L.

3.4.1 Likert scale questionnaire responses.

3.4.1.1 Questionnaire responses summary.

Scores for the eight statements on the questionnaires from each session are summarised in Figures 23-26.

3.4.1.1.1 Session 1 - Group 1.

Group 1 consisted of nine second-year audiology students. Figure 23 shows that, in general, responses to the statements lean more towards agreement than disagreement. All participants either agreed or strongly agreed that the session was well organised, that the tutor was able to communicate clearly, and that the session was useful for learning about cross-hearing. The two final statements, *I found maskME easy to use*, and, *I would recommend the session as a tool for first-year audiology students* elicited less agreement and more variable responses. 22% of participants disagreed that maskME was easy to use.

Two participants responded to two statements by circling in between *neutral* and *agree.* In order to keep the data simple to analyse, these responses were moved into the *agree* response group. The statements affected by this were *My ability to confidently recognise situations that need to be masked improved after the session* and *I think the session was useful for learning about the plateau.*

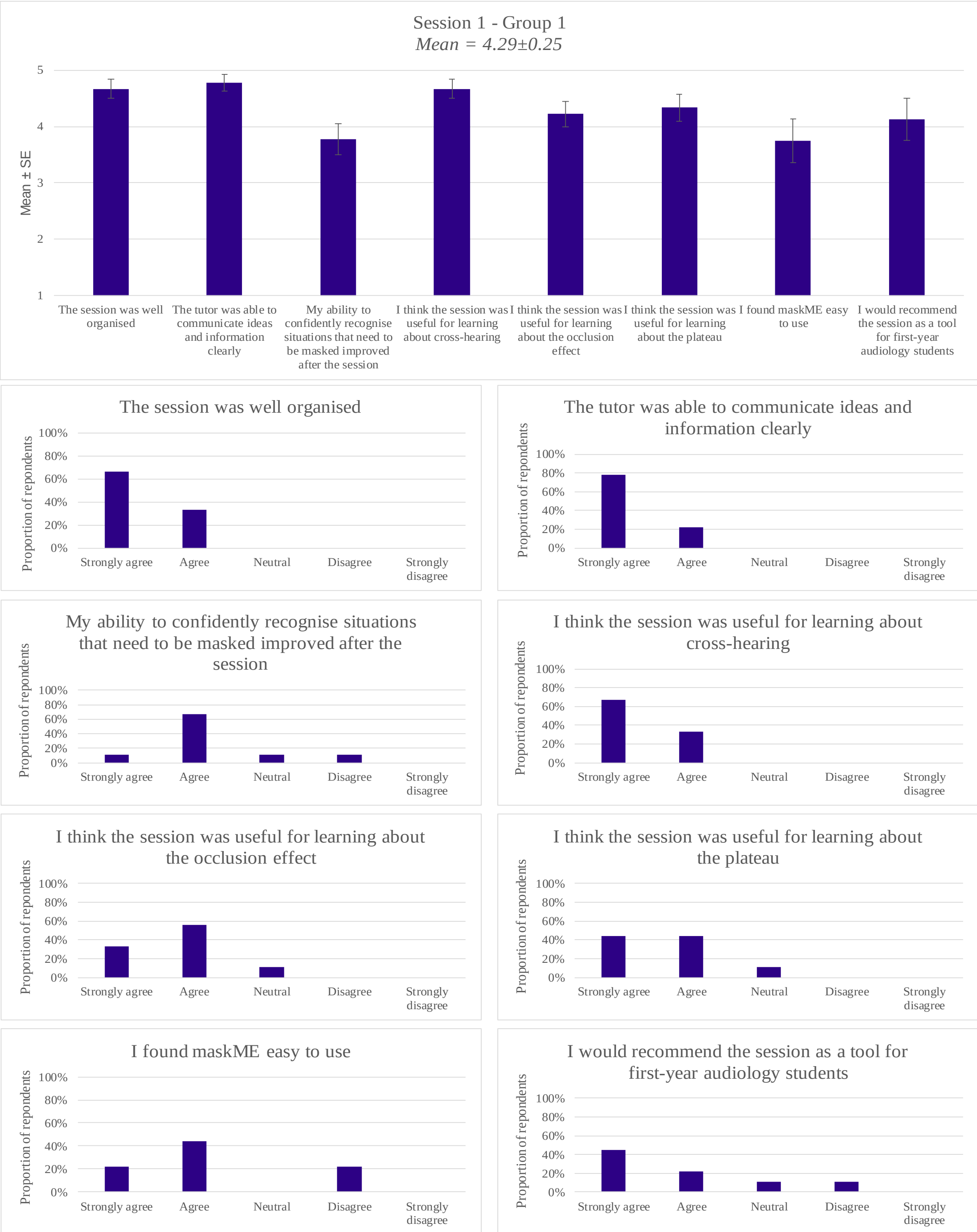


Figure 27: Group 1's responses to the questionnaire. The mean score for all statements was 4.29±0.25. This places the mean response to each of the eight statements between agree and strongly agree.

3.4.1.1.2 Session 2 – Group 2.

Group 2 consisted of ten first-year audiology students. Their responses are seen in Figure 24. The statements with the most responses in agreement were *The session was well organised* and *The tutor was able to communicate ideas and information clearly,* similar to Group 1. 80% of participants agreed or strongly agreed with the statement *I would recommend the session to first-year audiology students,* compared with 66% of Group 1. 50% of participants responded *neutral* or *disagree* to the statement *I found maskME easy to use*.

One participant responded to *My ability to confidently recognise situations that need to be masked improved after the session* by circling in between *neutral* and *agree.* As with Group 1, this response was changed to *agree* to more easily analyse the data.

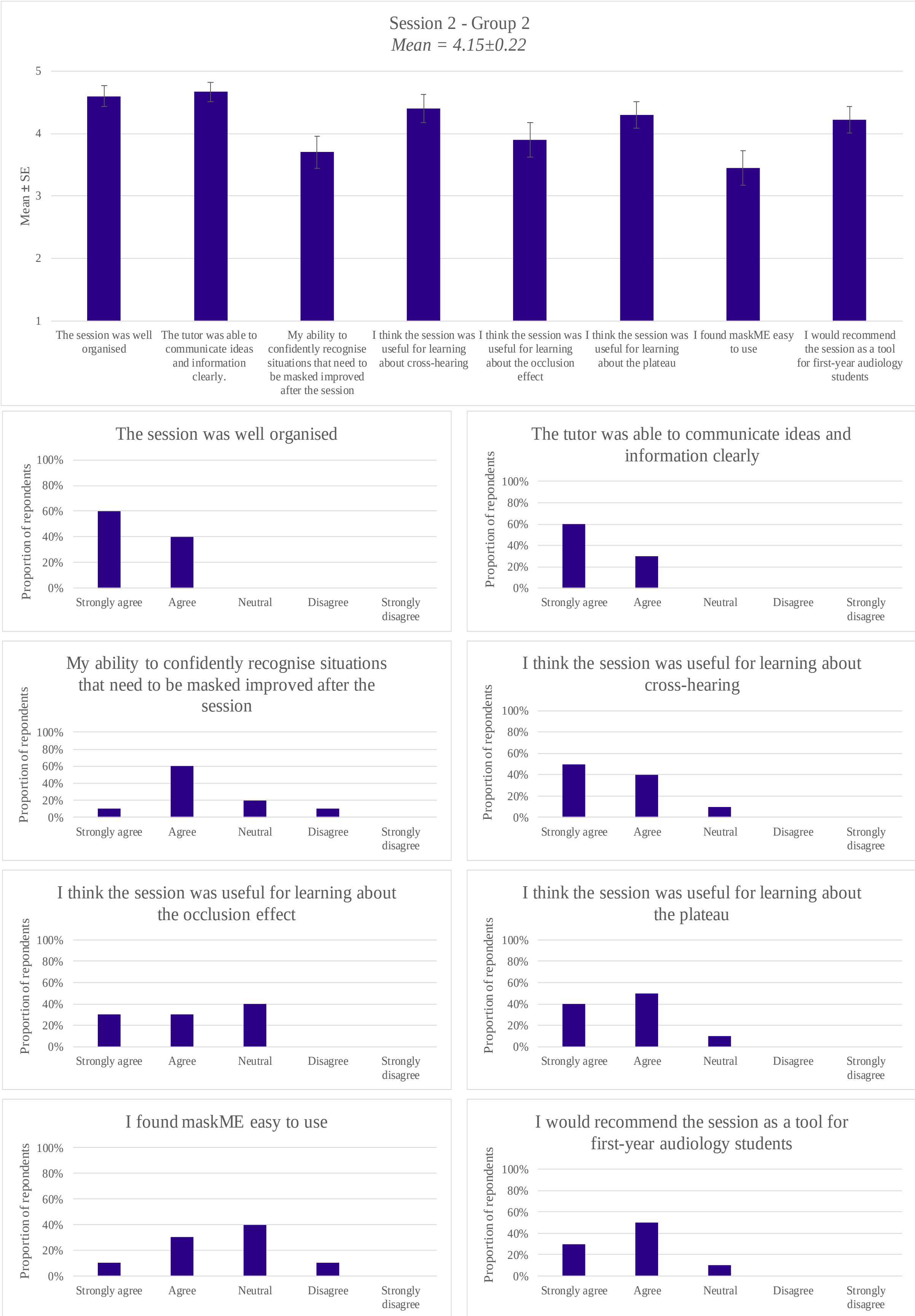


Figure 28: Session 2 summary of questionnaire responses. The mean score for all statements was 4.15±0.22. This places the mean response to each of the eight statements between agree and strongly agree.

3.4.1.1.3 Session 3 – Group 3.

Group 3 consisted of four novice participants whose responses can be seen in Figure 25. All participants responded to the statements with strongly agree, agree, or neutral; there were no responses in disagreement. Like Groups 1 and 2, participants agreed or strongly agreed that the session was well organised and that the tutor communicated clearly. Participants also responded this way to the statements regarding cross-hearing and the occlusion effect. The statement that elicited the most *neutral* responses was *My ability to confidently recognise situations that need to be masked after the session.* This is perhaps unsurprising, considering that these four participants had just been introduced to multiple novel concepts.

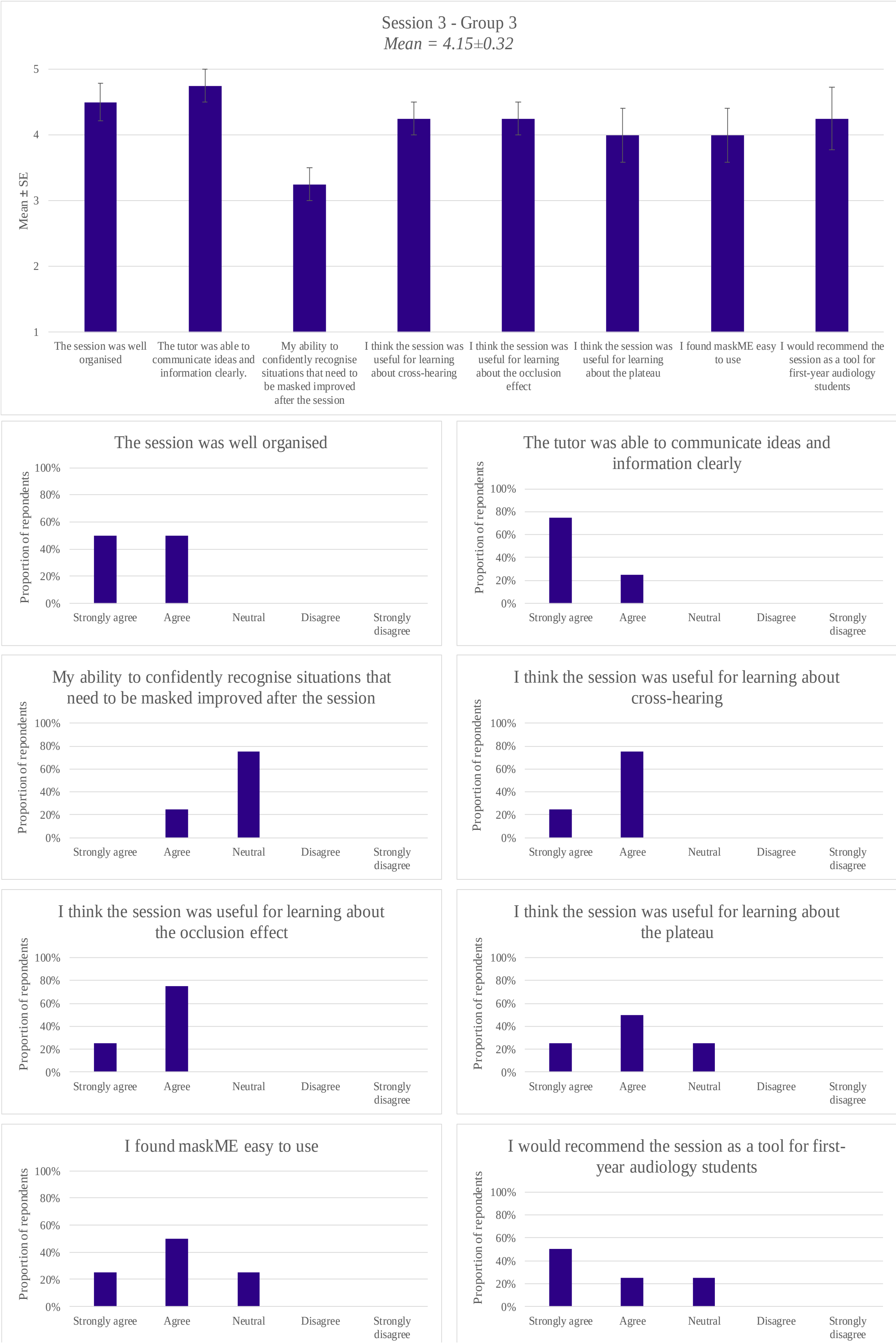


Figure 29: Session 3 summary of questionnaire responses. The mean score for all statements was 4.29±0.32. This places the mean response to each of the eight statements between agree and strongly agree.

3.4.1.1.4 Session 4 – Groups 4, 5 and 6.

Session 4 consisted of 32 participants: eight second-year audiology students, three first-year audiology students, and 21 novices. Their responses to the questionnaire are presented together in Figure 26. The statements with the most responses in agreement were *I think the session was well organised* and *I think the session was useful for learning about cross-hearing.* In responses to the statement *I found maskME easy to use,* 43% of participants agreed or strongly agreed, 34% responded with *neutral,* and 19% disagreed or strongly disagreed. Responses to this statement indicate that there was a variety of experiences with the software. 72% of participants or more agreed or strongly agreed with the statements regarding their ability to recognise situations that need to be masked, the occlusion effect, and that the session was useful for learning about the plateau. 69% of participants agreed or strongly agreed that they would recommend the session for first-year audiology students. One person responded with *strongly disagree* to this statement but left no additional comment explaining why.

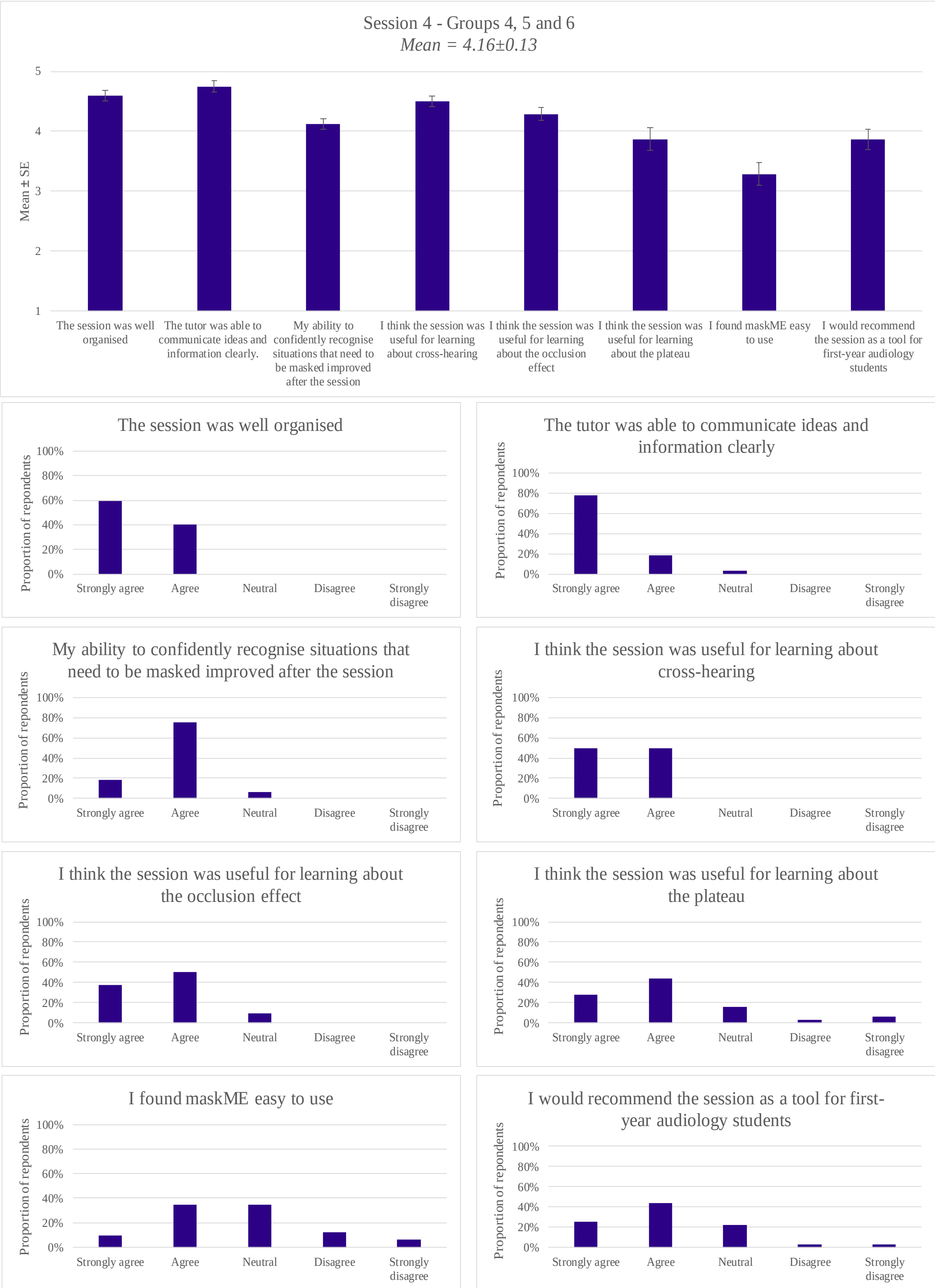


Figure 30: Session 4 summary of questionnaire responses. The mean score for all statements was 4.16±0.13. This places the mean response to each of the eight statements between agree and strongly agree, the same as the other four groups.

3.4.2 Open-ended questionnaire responses.

A sample of responses from each session are featured below, followed by some of the author's observations on what went well and what did not in each session. Responses have been recorded verbatim; errors in grammar or spelling were not corrected.

3.4.2.1 Session 1 – Group 1.

Group 1 consisted of nine second-year audiology students

List any positive aspects from today:

- The tool visually shows cross-over making it easy to see when there is likely to be cross-hearing or overmasking
- Learnt more about some things so feel like I understand most concepts better
- Display of information on the workbook was effective
- Good, clear information presented
- Easy to follow workbook and session.

What would you like to see changed in the session?

- A little more time (six participants responded with variations of this comment)
- The tool was quite confusing to use.

Anything else you think we should know?

- I think it's super helpful and would love to get the workbook/software to practise!

<u>Author observations from Session 1.</u>

Elements of the session that went well:

- Session 1 was booked in a large computer lab with a projector, allowing the author to easily demonstrate how to use maskME and use co-ordinating PowerPoint slides to explain concepts (see: Figure 27)
- Participants worked well together in groups of two or three, as encouraged by the author and workbook
- Participants were highly engaged with the session and activity: their conversations revolved around masking and they stayed on-task.

The main problems from this session were:

- The length of Quiz A. The author overheard several comments expressing worry regarding the size of the quiz and limited time to finish it. They were initially given ten minutes for the first quiz, but when the author realised that no participants had finished the quiz in that time, an additional seven minutes were given. This was still not enough time for the participants to finish the quiz. No more time could be given for the quiz due to the structure of the class. The same problem was encountered at the end of the session for the post-session quiz, but most participants were able to stay longer to finish it
- There was not enough time to finish all the plateau plotting activities in the workbook
- Only a small amount of time was spent on explaining both the occlusion effect and masking for speech audiometry. Three questions in Quiz A addressed these concepts.
- During the plateau plotting activities, the author overheard several comments expressing frustration about maskME. Most of the comments were about the difficulty experienced when changing level of the test tone and masking noise on the sliders

- There were about four people who were not part of the experiment who were using other computers in the computer lab. They stayed relatively quiet but it was at times distracting to have people coming and going.

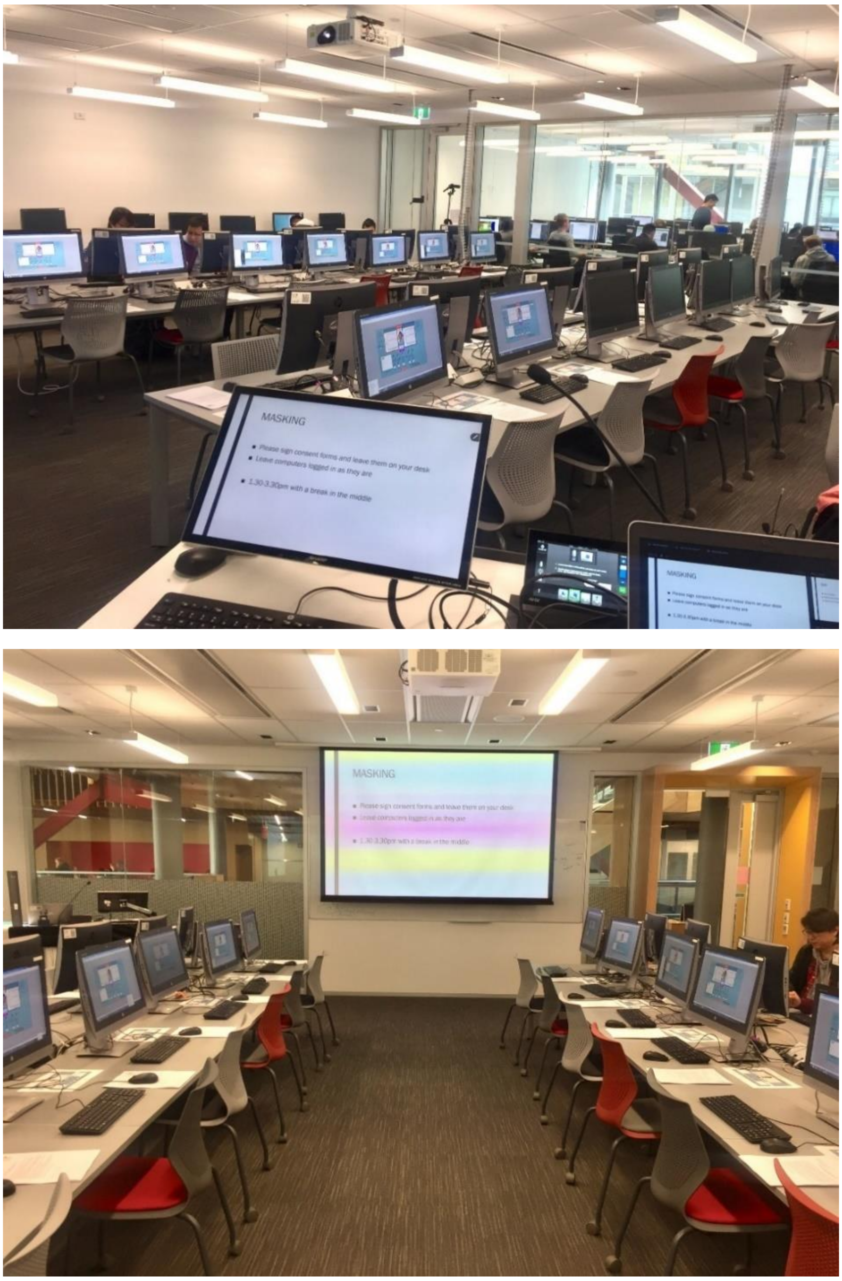


Figure 31: The large, modern classroom used for Sessions 1, 3 and 4.

3.4.2.2 Session 2 – Group 2.

Group 2 consisted of ten first-year audiology students. A sample of their feedback is provided.

List any positive aspects from today:

- Good handouts with clear explanations
- Helped provide some understanding that I was lacking before
- maskME was easy to use and understand
- Cases were helpful in assisting my learning
- Plateau was helpful and easy to understand.

What would you like to see changed in the session?

- We need more time for the session – it felt rushed and we skipped a lot of concepts that I was just about to understand. Maybe a PowerPoint would be helpful to explain than just showing on maskME.
- Maybe more instructions on how to do the masking steps/plots in maskME?
- maskME slider controls – make them a bit clearer and space between steps bigger or different way of controlling levels
- Maybe some on speech masking.

Anything else you think we should know?

- Main/only concern is with the software and how fiddly it is to change presentation level

- I just think the session needs to be longer to flesh out the concepts and not rush parts
- Going through steps of how you would test in clinic is helpful and how the equations are associate and why do we add OE. The LF OE was not explained therefore I put the same answer twice.

Author observations from Session 2.

Elements of the session that went well:

- Quiz B was able to be completed in the time given (20 minutes) by all participants, avoiding problems that Group 1 had with Quiz A
- Removing the section on masking for speech audiometry that Group 1 had allowed the participants to spend more time on learning concepts for pure-tone audiometry and practising plateau plotter activities
- Participants asked many questions throughout the session, indicating that they felt comfortable with the author presenting the session
- Participants worked together well in groups of two or three
- The group enjoyed the snacks provided by the author at the mid-session break.

The main problems from this session were:

- The session was booked in a different computer lab to Session 1. This computer lab was connected to another study space (see: Figure 28). Although technically the whole space was booked, there were about thirty other people coming and going, both using the computers and sitting at desks in the study space. The author could not empty the area, so Session 2's participants sat in two rows. The number of other people coming and going in the area did not create a comfortable environment to teach or learn in

- The computer lab also did not have a lecturer computer or projector, meaning that the author could not use the prepared PowerPoint or demonstrate how to use maskME on a large screen
- Several comments were made regarding how difficult it was to change the level of test tone and masking noise in maskME, including one participant saying “the software is janky”
- At times, the session felt rushed, particularly in the part where participants were doing the plateau plotting activities. Not all participants were able to finish all the activities in the workbook.

Figure 32: The room set-up for Session 2 with ten first-year audiology students. The session took place in the back two rows in the bottom photo. Other students used the remaining computers. The top photo shows how the room was linked to another study space.

3.4.2.3 Session 3 – Group 3.

Group 3 consisted of four novice participants. A sample of their feedback is provided.

List any positive aspects from today:

- Clear structure to study efficiently
- Easy to follow
- Repetition of main points helps to remember them
- maskME was very easy/simple to understand and use.

What would you like to see changed in the session?

- Possibly provide some more explanation for technical terms
- More focused on PowerPoint than workbook for theory, I find that more easy (sic) to follow
- Actually doing the experiment with headphones would be more informative in a sense that it would be an immersive experience and therefore more memorable in the head.

Anything else you think we should know?

- A lot of information at once maybe better split in 2 sessions.

Author observations from Session 3.

Elements of the session that went well:

- The session was presented in the same room as Session 1 with a projector, and there was no one in the room who was not participating in the study
- The timing of the session was better than that of Sessions 1 and 2. Not all participants finished all workbook activities, but the pace was more relaxed as the session was three hours (compared to two hours for Sessions 1 and 2)
- Participants were generally quite engaged in the session and appeared comfortable asking the author questions
- After the second break and before the last section of the session, the author briefly reviewed all the concepts covered so far. The concepts were listed on the front of their workbooks. Participants seemed to like the reviewing of concepts throughout the session
- The author went two extra full examples of plotting the plateau using maskME. This was not planned, but the participants seemed to be confused over some concepts, therefore it was deemed appropriate.

The main problems from this session were:

- Twelve people had signed up to participate in the session but only four attended. One person arrived to participate then left, not having realised that the session was three hours long. One to-be-participant emailed the author thirty minutes into the session explaining that she had got lost on campus. This was remedied in Session 4 by sending out a reminder email the day before to all participants with details of the study, including a map

- There was little collaboration between the participants
- The author noticed that the participants were struggling to move the sliders in small steps
- There were displays of confused facial expressions during the session
- Participants did not understand the Hood procedure of masking well and needed extra explanations of how to perform it. This was remedied in Session 4 by providing an infographic of steps in the procedure
- It felt like there was a lot of information at once, especially considering the participants had an extra initial presentation on hearing and hearing testing before starting with the masking content
- maskME did not work on the author's laptop which was being used to demonstrate the programme to the class. It had been working the before the class during a check, so it was unclear what had happened. The author therefore used a computer alongside the participants to demonstrate maskME.

3.4.2.4 Session 4 - Groups 4, 5 and 6.

Group 4 consisted of eight second-year audiology students, Group 5 of three first-year audiology students and Group 6 of 21 novice participants. A sample of their feedback is provided.

List any positive aspects from today:

Groups 4 and 5: audiology students

- PowerPoints (three participants listed this)

- Kahoot quizzes (five participants listed this)
- Clear concise explanations from instructor
- Pace
- Shorter quiz was easier to finish on time.

Group 6: novice participants

- Well organised
- Clear presentation and flow of ideas
- Competitive, unmarked class quiz was very fun and helpful for revising concepts (Kahoots)
- Interactiveness of the session, Kahoot quizzes were good to consolidate what was learned through workbook.

What would you like to see changed in the session?

Groups 4 and 5

- Move through concepts slower slightly
- Improved software
- maskME takes a bit of time to fully understand (eleven participants had negative comments about maskME).

Group 6: novice participants

- It would be more easy if are yet more details regarding how to handle the software
- Less quiz
- More person-to-person help when using maskME
- More examples and picture guides for showing how to use maskME

- Split to multiple shorter sessions.

Anything else you think we should know?

Groups 4 and 5

- Not having to manually clear each session on the plateau graph when the case is changed (maskME).

Group 6: novice participants

- Wow, audiology is really complicated. Brain = melted ☺.

<u>Author observations from Session 4.</u>

Elements of the session that went well:

- The number of participants that attended, especially for the novice group (21 people)
- The session was in the same room as Sessions 1 and 3, with a projector. There was nobody in the room who was not taking part in the experiment
- The timing and pace of the session was improved from previous sessions. The three breaks over the three hours kept the session moving well
- Nearly all participants worked collaboratively with at least one neighbour
- During the presentation on hearing and hearing testing for novice participants, the author adhered visuals to the whiteboard of that displayed parts of the ear and transducers with their interaural attenuation values. Having visual aids to refer back to during the teaching of masking concepts was helpful for the author

- The infographic of the Hood procedure was helpful for the novice participants for the plateau plotting activities
- All participants finished Quiz C and the questionnaire in under 20 minutes
- One audiology student who had also attended Session 1 reported that Session 4 was much better: that the pace was more relaxed, the visuals and PowerPoints were better, and she liked having more time to do the activities
- Participants seemed to highly enjoy the two Kahoot quizzes
- The session had a more relaxed and fun ambiance than previous sessions, aided by the Kahoot quizzes, music during the breaks, and frequent breaks.

The main problems from this session were:

- The author had not installed maskME files correctly on about ten computers so some participants (mainly audiology students) had to wait to start the activities
- There was a fair bit of frustration with using the software, especially the sliders, from both audiology students and novice participants
- There was some confusion from novice participants around the plateau concept but they appeared to get the hang of it after doing some examples
- Turnout from the first-year audiology student cohort was quite low (three) compared to their first session, where ten students came.

3.4.3 Summary of Research Question 3.

Research question 3 set out to investigate whether participants perceive the session and maskME as useful for learning masking concepts. Most participants left helpful and constructive feedback in the questionnaires, giving in-depth insight into their experiences in the sessions and with maskME.

The responses to the Likert-scale questions on the questionnaires were generally positive across all groups and all sessions. The average response for any participant at any session was between *agree* and *strongly agree*.

Responses to the open-ended feedback questions were consistent with the Likert-scale responses, particularly regarding positive comments about the organisation of sessions and negative comments regarding how easy maskME was to use.

4 Discussion

Masking in audiology is known to be difficult to teach and learn. Using computer-based simulators in audiological education has the potential to help students understand the underlying concepts of masking. The present study found that declarative knowledge of masking concepts increased for audiology students who completed a session on masking using maskME. The non-audiology student participants who received a session on masking with maskME had significantly worse quiz scores than the audiology students', but were able to retain some knowledge of the content with a mean quiz score of 48.02±16.01%. And lastly, this study found that all participants perceived the session and maskME as a beneficial tool for learning masking.

4.1 Research Question 1

Does audiology student participants' knowledge of the concepts of masking improve between assessments?

Quiz scores demonstrated that both first-year and second-year audiology students scored higher in the post-session quiz than in the pre-session quiz. The increase in pre- and post-session scores was statistically significant for the first session attended by each group. This supports the hypothesis that their knowledge of masking concepts did improve after a session on masking with maskME. This was not an unexpected outcome, as all audiology student participants had prior knowledge of both masking concepts and procedures. This finding is in line with previous research by Durham et al. (1994), Lieberth and Martin (2005) and Sitzmann (2011) that found that knowledge increased after a lesson featuring the use of computer-based simulators.

4.2 Research Question 2

How does a group of non-audiology students score on a masking quiz following a session on hearing and masking?

Because there were so few studies that compared performance between audiology students and novices at the time of writing, a hypothesis was not made for this research question. This particular research question was therefore exploratory in nature.

Two groups of novices were used in this study to pilot the resources created for teaching masking with maskME. The mean quiz score for the first group (Group 3, n=4) was 56.25±0.17% and for the second group (Group 6, n=21) was 48.02±16.01%.

Group 6 attended Session 4, which was also attended by audiology students. Both novices and audiology students completed the same post-session quiz, and results showed that the novices scored significantly worse than the audiology students. This study discovered that a session on masking using maskME with novices was not enough to bring novices' declarative knowledge of masking up to the same level as audiology students. This is perhaps unsurprising, given the complexity of the interacting underling concepts of masking, detailed throughout this research. The purpose of recruiting novices for this project was to try and mimic the stage at which first-year audiology students would typically be at when they first learn about masking. At UC, masking is taught within the first four weeks of the course, but first-year students have knowledge from other classes in the course to help integrate the concepts of masking. The novices in this study were given a 20-minute presentation on the basic tenets of hearing and hearing testing, but that may not be enough.

The two studies which also used novices to test computer-based simulators in audiological education were by Lieberth and Martin (2005) and Guard (2013). Lieberth and Martin found that novices were able to score similarly to audiology students on a practical test, achieving a mean score of 73.35% compared to 78.95% for the audiology students. Guard used two groups of novice (or near-novice) participants for her audiology research with a computer-based simulator who had mean scores on a written assessment of 48.77% and 69.6%. The present study's results are more in line with Guard's results than with Lieberth and Martin's, suggesting that novices to audiology may need more time and practise to score well on a masking quiz.

4.3 Research Question 3

Do participants perceive the masking session and maskME as useful for learning masking concepts?

Results from the questionnaires were generally positive, with mean scores for each of the eight Likert-scale statements ranging between *agree* and *strongly agree*. The hypothesis that students would perceive the masking session and maskME as beneficial for learning masking concepts was supported, in line with previous research by Wilson et al. (2010), Sistrunk (2002), Sanderson (2012), Guard (2013) and Howland (2012). Participants also provided open-ended feedback and detailed positive and negative aspects of the session. There was mixed feedback regarding how easy maskME was to use, suggesting there is room for improvement in the software design.

4.4 Methodological considerations and suggests for future research

Several methodological limitations were identified in the present study which should be considered when interpreting the results and generalisability of the results. Limitations are detailed and then accompanied by suggestions for further research.

4.4.1 Lack of control groups.

Since this study did not have control groups, the effect of maskME on learning and understanding masking concepts remains unknown. It is possible that the traditional way of teaching masking (via lectures) could have led to the same results. The purpose of the present study was purposefully kept narrow was to pilot and refine newly created resources to teach masking. This limitation could be remedied in a future study by having one group of novices who receive a training session with maskME and a group that receive a traditional lecture.

4.4.2 Participant numbers.

The size of the four groups of audiology students were all small, ranging from three to ten participants. This was due to the realities of recruiting from two small classes of only 16 students each. The size of the first novice group, four participants, was also a limitation. This was addressed for Session 4 by increasing the token of appreciation and emailing all participants the day before to remind them and give directions. Although the first group of novice participants was small, it did allow the researcher to use that session as a practice session before running Session 4, which had 32 participants from three different groups of people including 21 novices. Sampling from the small pool of audiology students will be challenging while the class sizes remain as small as they currently are in New Zealand.

4.4.3 Normality in quiz score data.

For Group 4, non-parametric tests, which have less statistical power than their parametric counterparts, had to be used to compare pre-and post-session quiz scores due to a non-normal distribution of data. This problem was likely due to the small number of participants (n=8) and could be remedied by increasing sample size in future research.

4.4.4 Session 2's room.

The room that Session 2 (first-year audiology students) was held in did not have a projector or teacher lectern. There were also approximately 30 other people using the room as a quiet study space, with some people coming and going. Photos of this room can be seen in Figure 25. This set-up led to complications in delivering the content as had been planned with accompanying visuals. It is possible that participants in this group were disappointed with the session because of this, which could have been part of the reason why only three first-year students came to Session 4. Care was taken to book Sessions 3 and 4 in a more appropriate room for the following sessions.

4.4.5 Session 4 scheduling.

It may have been better to schedule Session 4 on a weekday and not on the Saturday morning after a term ended to encourage more first-year audiology student participation. The session was three hours long, which could have discouraged potential participants from wanting to attend. In future similar studies, it may be more participant-friendly to have two smaller sessions over a week instead of one relatively long class.

4.4.6 maskME in Session 4.

In Session 4, maskME was not loaded correctly onto about ten computers, so there was some delay for some students to start the activities. Priority was given to novice participants' computers, then to audiology students' computers as most audiology students had already come to a session. This was an oversight on the author's behalf but was fortunately easily fixed within ten minutes (while other participants worked on activities in their workbooks) at the time.

4.4.7 Speech masking.

Although it would have been optimal to include speech masking in the sessions, it became apparent after Session 1 that there was not enough time to do so. Speech masking content in the PowerPoint slides, workbook and quizzes were subsequently removed for Session 2-4. In future, a separate session on speech masking could be created, alongside more specific functions in maskME to deal with speech stimuli.

4.4.8 Novice participants' language and academic ability.

Novice participants did not have to be native speakers of English, and the author observed that all four novices in Session 3 were non-native English speakers, as were over half of the 21 novices in Session 4. Although most seemed to have an adequate understanding of English, there were two participants in particular in Session 4 whose English level did not appear to be very advanced. This could have impacted their understanding of the lesson and ultimately their quiz scores. To gain entry to the Master of Audiology, students must have a sufficient fluency in English (at least an International English Language Testing System (IELTS) score of 6.5) so it could be warranted to only accept participants with that level of English or above. In addition, entry into the Master of Audiology course requires at least a B+ average from previous studies. Novice participants were not recruited on the basis of their grades or previous studies, resulting a much more varied sample. This limitation could also relate to the novices' quiz scores.

4.4.9 Participant self-selection.

Participant self-selection is always a limitation in research: perhaps only the more motivated audiology students came to the sessions, or only came out of a sensed peer obligation. It was made clear to the audiology students that the sessions were voluntary and not necessary for their learning. Considering the time and mental effort required to participate in the study, it is possible that the novice participants were only motivated by the token of appreciation. This does not discount their efforts, quiz scores or questionnaire responses, but should be acknowledged.

4.4.10 Quiz questions and length.

Quizzes A and B each contained two questions which were ultimately excluded because the answers to them were not addressed properly in the sessions. These questions were:

- *Does the occlusion effect affect both ears when the masking transducer is only occluding one ear? Why or why not?* (Quiz A and B)
- *Why do we need to add extra masking noise to compensate for the occlusion effect?* (Quiz A)
- *For low frequency sounds (1000Hz and under) in masked bone conduction threshold testing, more masking is required to compensate for the OE. Why is more masking noise needed?* (Quiz B)

There was not enough time to adequately cover these concepts during the sessions because other activities took longer than expected, which is why answers for them were excluded from the score count. Some participants may have spent a relatively long amount of time answering those questions, leaving them less time for other questions. Unfortunately, the author cannot know if that was indeed the case for anyone, and if so, for whom. This could have created an unfair grade for some participants.

Quiz A was too long for the time given (17-20 minutes) and many participants were unable to finish it, which likely affected their scores. Because the sessions were not teaching the audiology student participants anything new, it was possible that a plateau or ceiling effect would be observed in the quiz scores.

4.4.11 Education background of the author.

Neither the author nor principal supervisor were trained formally in education, which could have affected the lesson planning. In future, an education expert could be consulted during the development phase.

4.4.12 Suggestions for improvements to maskME.

There is still room for improvement for maskME and some suggestions are detailed below based on participant feedback and author observation.

- Enabling the use of keyboards to use buttons and change the intensity or frequency of the test tone or masking noise. There were several comments in the open feedback part of the questionnaire suggesting this change. For example, the right arrow could be used to increase the frequency of the test signal and the down arrow could be used to decrease the intensity. The shift key could be used with an arrow to change the intensity of the masking. The space bar or enter button could be used to plot a point on the plateau plotter. There are common shortcuts used in audiometry computer programmes, so it would make sense to make these changes in line with popular clinical software.
- A new function could be added to address speech masking. While speech masking was not a focus of this project, it would be useful for students to be able to practise masking for speech.
- Sounds could be added so that users could hear how increasing the masking noise “drowns out” the test signal. This was suggested in the questionnaire by a novice participant from Session 3.
- maskME needs to be able to fully incorporate the significance of the occlusion effect button. Currently, when enabled, the OE button raises the bone conduction thresholds of the non-test ear. However, when the user goes to mask a threshold with the button

on, the results are incorrect. The primary supervisor tried to remedy this problem but it was not possible.

- Finally, the aesthetic of the programme needs changing. Changes were suggested by the author but were not able to be made. The current front panel of maskME is crowded and looks outdated. The author heard several comments from participants regarding how maskME looked in the sessions, and several people left comments in the questionnaire suggesting that changes be made.

Once changes have been made to make it more user-friendly, attractive and intuitive, audiology students worldwide could use maskME to practise masking. It would be beneficial for students if maskME were freely available online to download and use on their personal computers. Short instructional videos on how to use maskME could be uploaded on YouTube to help people use the software on their own.

4.4.13 Scope of project.

Masking is a complex topic in audiology and ultimately must be practised with real patients or clients. While it was not a goal of this particular study to develop interpersonal or procedural skills, students who go on into audiologist roles must perform it regularly, limiting this project's clinical relevance.

4.5 Conclusion

Complex topics may be better taught in audiology education by including the use of computer-based simulators into the course. Masking is a prime example of such a topic, and maskME is a piece of software which could be useful because it presents the underlying concepts of masking in a visually novel format. This study found that declarative knowledge of masking increased after a session on masking with maskME for audiology students, and demonstrated the limits of such a session on novices to audiology. The participants in this study provided detailed feedback of positive elements of the sessions, along with suggestions for improvement. Mean scores from Likert scale statements rating the usefulness of the session and maskME for understanding various masking concepts were generally positive in nature. The results are encouraging and indicate that maskME may be a useful tool for teaching masking to audiology students.

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Appendices A-L

Appendix A: Ethical approval

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Rebecca Robinson
Telephone: +64 03 369 4588, Extn 94588
Email: human-ethics@canterbury.ac.nz

Ref: 2018/25/ERHEC

22 June 2018

Anna Moginie
Communication Disorders
UNIVERSITY OF CANTERBURY

Dear Anna

Thank you for providing the revised documents in support of your application to the Educational Research Human Ethics Committee. I am very pleased to inform you that your research proposal "Changes to the Teaching of Clinical Masking for Audiology Students, Including a New Software-Based Teaching Tool, "maskME"" has been granted ethical approval.

Please note that this approval is subject to the incorporation of the amendments you have provided in your emails of 20th and 22nd June 2018.

Should circumstances relevant to this current application change you are required to reapply for ethical approval.

If you have any questions regarding this approval, please let me know.

We wish you well for your research.

Yours sincerely

pp R. Robinson

Dr Patrick Shepherd
Chair
Educational Research Human Ethics Committee

Please note that ethical approval relates only to the ethical elements of the relationship between the researcher, research participants and other stakeholders. The granting of approval by the Educational Research Human Ethics Committee should not be interpreted as comment on the methodology, legality, value or any other matters relating to this research.

F E S

Appendix B: Advertising

B.1. Advertising for first-year audiology student (Group 2) participant recruitment

ATTENTION FIRST YEAR AUDIOLOGY STUDENTS!

Masking session!

Research project: Changes to the teaching of clinical masking for audiology students, including a new software-based teaching tool, 'maskME'

What? We're creating new resources to learn and practise masking, and need to evaluate them! I'll be running a two-hour session on masking where we will revise the concepts of masking and do some activities

How much? $20 Westfield voucher given at the end of the session

Where? Kotuku 101 computer lab at the *Dovedale Campus*

When? Monday 27th August from 1.30pm-3.30pm

What do I do in the session?

1. Refresh learning about masking
2. Practise new and refreshed knowledge with the software 'maskME'
3. Complete two quizzes on masking and a questionnaire on the session

Master of Audiology student: Anna Moginie
Project supervised by Alison Cook and Greg O'Beirne

Interested? Let me know on Facebook, 0204 121 7891 or anna.moginie@pg.canterbury.ac.nz

anna.moginie@pg.canterbury.ac.nz
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
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Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Audiology research – masking lesson

B.2. Advertising for second-year audiology student (Group 1) participant recruitment

Attention second year audiology students

Participate in research!

Master of Audiology student: Anna Moginie

Research project: Changes to the teaching of clinical masking for audiology students, including a new software-based teaching tool, 'maskME'

What? We're creating new resources to learn and practise masking and need to evaluate them! I'll be running a two-hour session on masking where we will revise the concepts of masking and do some activities

How much? $20 Westfield voucher - given at the end of the session

Where? Erskine 010 Computer Lab

When? Friday 17th August. 1.30pm – 3.30pm

What do I do in the session?

1. Refresh learning about masking
2. Practise new and refreshed knowledge with the software 'maskME'
3. Complete two quizzes on masking and another on the session

Interested? Let me know - anna.moginie@pg.canterbury.ac.nz

Project supervised by Alison Cook and Greg O'Beirne

anna.moginie@pg.canterbury.ac.nz
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Audiology research – masking lesson

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anna.moginie@pg.canterbury.ac.nz
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Audiology research – masking lesson

B.3. Advertising for novice Group 3 participant recruitment

Participate in audiology research!

Research project: Changes to the teaching of clinical masking for audiology students, including a new software-based teaching tool, 'maskME'

Master of Audiology student: Anna Moginie

Supervised by Alison Cook and Greg O'Beirne

What is masking?! Masking is part of a hearing test. It helps the tester get true results from each ear, like using an eye patch in eye tests.

Where? Rutherford 212 computer lab

How long? 9am – 12pm (with breaks!)

Date: Monday 17 September

What do I do in the session?

1. Learn about hearing tests
2. Work through some examples
3. Complete a short quiz on masking and a questionnaire on the session

Who can participate? Anyone who has had ***no*** experience with learning about hearing tests or masking in audiology

How much? $20 Westfield voucher given at the end of the session

Interested? Contact Anna at anna.moginie@pg.canterbury.ac.nz or on 0204 121 7891

anna.moginie@pg.canterbury.ac.nz
Monday 17 Sep, 9am – 12pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Monday 17 Sep, 9am – 12pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Monday 17 Sep, 9am – 12pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Monday 17 Sep, 9am – 12pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Monday 17 Sep, 9am – 12pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Monday 17 Sep, 9am – 12pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Monday 17 Sep, 9am – 12pm
Audiology research – masking lesson

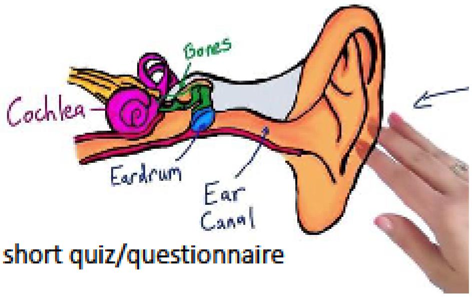
anna.moginie@pg.canterbury.ac.nz
Monday 17 Sep, 9am – 12pm
Audiology research – masking lesson

B.4. Advertising for novice Group 6 participant recruitment

Participate in research!

We are experimenting with a new way of teaching an important part of hearing testing, called *masking*. We are running a 3 hour workshop on masking (2 x 90-minute sessions) and we'd like you to take part!

What is masking?! It helps the tester get true results from each ear, like using an eye patch in eye tests.



What do I do in the sessions?

1. Learn about hearing and hearing testing
2. Learn how to do masking
3. Work through a few examples & complete a short quiz/questionnaire

Where? Ernest Rutherford 212 computer lab

When? Saturday 20th October
9.30 am – 12.30 pm
(with breaks!)

Research project: ***Changes to the teaching of clinical masking for audiology students, including a new software-based teaching tool, 'maskME'***

Master of Audiology student: Anna Moginie

Supervised by Alison Cook and Greg O'Beirne

What's in it for me? Two $20 Westfield vouchers- one per session

Who can participate? Anyone who has had ***no*** experience with learning about hearing tests or masking in audiology

Interested? Contact Anna at anna.moginie@pg.canterbury.ac.nz or on 0204 121 7891

anna.moginie@pg.canterbury.ac.nz
Sat 20th Oct, 9.30am – 12.30pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Sat 20th Oct, 9.30am – 12.30pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Sat 20th Oct, 9.30am – 12.30pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Sat 20th Oct, 9.30am – 12.30pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Sat 20th Oct, 9.30am – 12.30pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Sat 20th Oct, 9.30am – 12.30pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Sat 20th Oct, 9.30am – 12.30pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Sat 20th Oct, 9.30am – 12.30pm
Audiology research – masking lesson

anna.moginie@pg.canterbury.ac.nz
Sat 20th Oct, 9.30am – 12.30pm
Audiology research – masking lesson

B.5. Advertising for first- and second-year audiology students (Groups 4 and 5)

Another masking session!

What happens in the session?

1. Refresh masking knowledge
2. Do some masking using maskME, a piece of custom-made software
3. Complete two short quizzes and a questionnaire

Who can come?

Any audiology student in first or second year!

You can come even if you didn't come to the first session

This session will be very similar to the first session but not identical. This one is split into 2 90-minute sessions

When and where is it?

Saturday October 20th

9.30am – 12.30pm with breaks!

Rutherford 212 computer lab

Research project: *Changes to the teaching of clinical masking for audiology students, including a new software-based teaching tool, 'maskME'*

Master of Audiology student: Anna Moginie

What's in it for me?

All participants will receive *two* $20 Westfield vouchers as a token of appreciation – one voucher per session

Interested? Contact Anna at anna.moginie@pg.canterbury.ac.nz, on 0204 121 7891 or via Facebook

Appendix C: Information and consent forms

C.1. Information sheet for audiology student participants

Department of Communication Disorders
Telephone: +64 3 369 4827
Email: anna.moginie@pg.canterbury.ac.nz
17 August 2018

Changes to the teaching of clinical masking for audiology students, including a new software-based teaching tool, 'maskME'

Information sheet for audiology student participants

My name is Anna Moginie and I am in my second year of the Master of Audiology course at the University of Canterbury. My research involves creating a new curriculum to teach clinical masking to audiology students. Masking is part of hearing tests that helps the tester get true results from each ear. It involves putting a white noise sound into one ear to distract it from helping the other ear.

If you choose to take part in this study, your involvement in this project will involve coming to one two-hour session at university. I'll be video recording myself giving the lecture but participants will not feature in the video. There are three groups of participants: first year audiology students, second year audiology students, and a group of non-audiology students. Audiology students will participate in one session and non-audiology students will participate in two sessions.

The session will involve: learning (or revising) the key concepts of masking, using the software maskME to practise masking, completing two short, paper-based quizzes and filling out a questionnaire about your experiences of the teaching programme. maskME is an interactive software teaching tool, which allows the user to visualise the process of masking. This session is not necessary for learning the concepts of masking: your lectures and clinical practice are sufficient. It is a stand-alone session: you do not need to revise masking beforehand.

The results of the project may be published in unidentified form, and you can be assured of the complete confidentiality of data gathered in this investigation: your identity will not be made public at any stage. You will use your student ID number as your unique code, which will not be compared against your university records at any stage. Only I will have access to data with your ID number on it. My supervisors, Alison Cook and Greg O'Beirne, will not see your ID number if they look at the data. There is no link to your grades from this research and no other lecturers will be able to identify you.

You may come to the session but choose not participate in the research. Participation is voluntary and you have the right to withdraw before the 19th of October 2018. You may ask for your raw data to be returned to you or destroyed before the 19th of October 2018. If you withdraw, I will remove any information relating to you. A thesis is a public document and will be available through the UC Library. If you choose to participate in the study, you will receive a $20 Westfield voucher as a token of appreciation. These will be distributed after your role in the project has been completed. You may keep the voucher if you choose to withdraw from the study.

The project is being carried out as a requirement for the Master of Audiology degree by Anna Moginie under the supervision of Alison Cook and Greg O'Beirne. They can be contacted at alison.cook@canterbury.ac.nz or gregory.obeirne@canterbury.ac.nz, and are able to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Educational Research Human Ethics Committee, and participants should address any complaints to The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

If you agree to participate in the study, please complete the consent form and return it to me.

Thank you

Anna Moginie
Master of Audiology student

C.2. Information sheet for novice participants

Department of Communication Disorders
Telephone: +64 3 369 4827
Email: anna.moginie@pg.canterbury.ac.nz
26 September 2018

Changes to the teaching of clinical masking for audiology students, including a new software-based teaching tool, 'maskME'

Information sheet for non-audiology student participants

My name is Anna Moginie and I am in my second year of the Master of Audiology course at the University of Canterbury. My research involves improving the way masking is taught to audiology students. Masking is part of hearing tests that helps the tester get true results from each ear. It involves putting a white noise sound into one ear to distract it from helping the other ear. It’s similar to wearing an eye patch on one eye when getting your eyes tested in order to isolate each eye. The purpose of this study is to evaluate new resources to teach masking.

If you choose to take part in this study, your involvement in this project will involve coming to a session at university. It will last three hours. I’ll be video recording myself giving the lecture but participants will not feature in the video. There are three groups of participants: first year audiology students, second year audiology students, and a group of non-audiology students.

The session will involve: learning the key concepts of masking, using the software maskME to practise masking, completing a short, paper-based quiz, and filling out a questionnaire about your experiences of the teaching programme. maskME is an interactive software teaching tool which allows the user to visualise the process of masking.

The results of the project may be published in unidentified form, and you can be assured of the complete confidentiality of data gathered in this investigation: your identity will not be made public at any stage. You will use your student ID number as your unique code, which will not be compared against your university records at any stage. Only I will have access to data with your ID number on it. My supervisors, Alison Cook and Greg O’Beirne, will not see your ID number if they look at the data.

Participation is voluntary and you have the right to withdraw before the 19th of October 2018. You may ask for your raw data to be returned to you or destroyed before the 19th of October 2018. If you withdraw, I will remove any information relating to you. A thesis is a public document and will be available through the UC Library. If you choose to participate in the study, you will receive a $20 Westfield voucher as a token of appreciation. These will be distributed after your role in the project has been completed. You may keep the voucher if you choose to withdraw from the study after completing the second session.

The project is being carried out as a requirement for the Master of Audiology degree by Anna Moginie under the supervision of Alison Cook and Greg O'Beirne. They can be contacted at alison.cook@canterbury.ac.nz or gregory.obeirne@canterbury.ac.nz, and are able to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Educational Research Human Ethics Committee, and participants should address any complaints to The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

If you agree to participate in the study, please complete the consent form and return it to me.

Thank you

Anna Moginie
Master of Audiology student

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

C.3. Consent form for participants

Department of Communication Disorders
Telephone: +64 3 369 4827
Email: anna.moginie@pg.canterbury.ac.nz

Changes to the teaching of clinical masking for audiology students, including a new software-based teaching tool, 'maskME'

Consent form for participants

- ☐ I have been given a full explanation of this project and have had the opportunity to ask questions.
- ☐ I understand what is required of me if I agree to take part in the research.
- ☐ I understand that participation is voluntary and I may withdraw at any time without penalty. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.
- ☐ I understand that any information or opinions I provide will be kept confidential to the researcher and her supervisors, Alison Cook and Greg O'Beirne, and that any published or reported results will not identify the participants. I understand that a thesis is a public document and will be available through the UC Library.
- ☐ I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after five years.
- ☐ I understand that I can contact the researcher, Anna Moginie at anna.moginie@pg.canterbury.ac.nz, or supervisor Alison Cook at alison.cook@canterbury.ac.nz for further information. If I have any complaints, I can contact the Chair of the University of Canterbury Educational Research Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)
- ☐ I would like a summary of the results of the project.
- ☐ By signing below, I agree to participate in this research project.

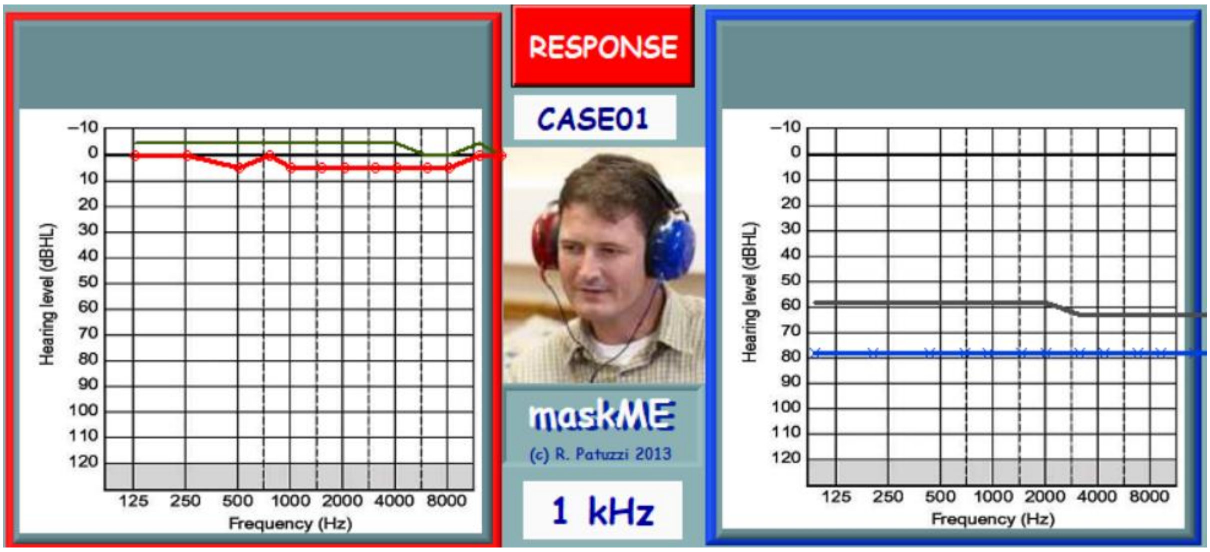
Name:____________________________ Signed:__________________________ Date:_______________

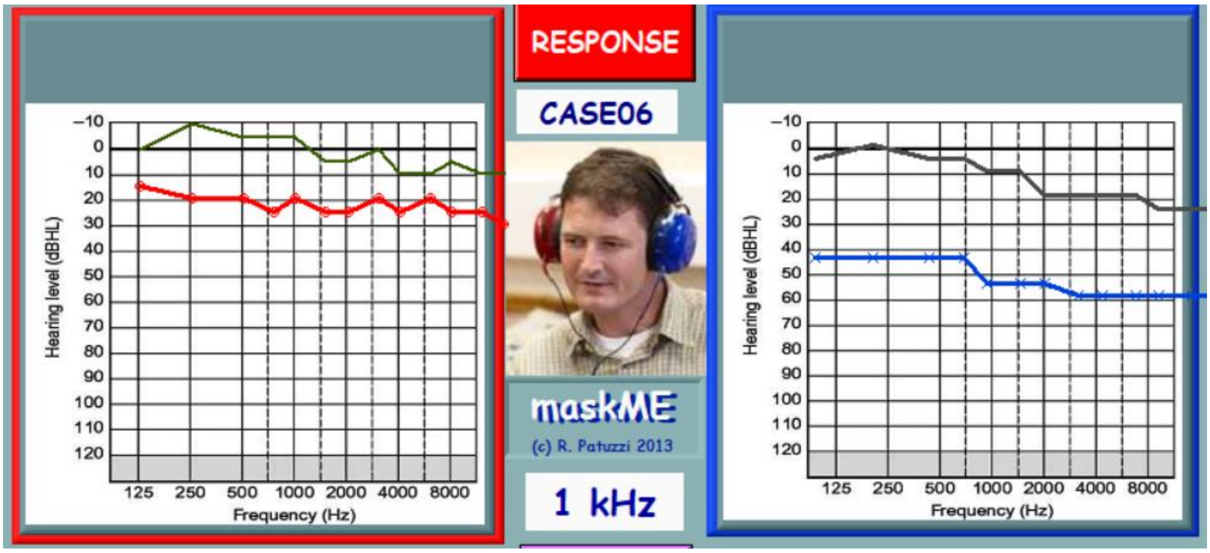
Email address *(for report of findings, if applicable)*:____

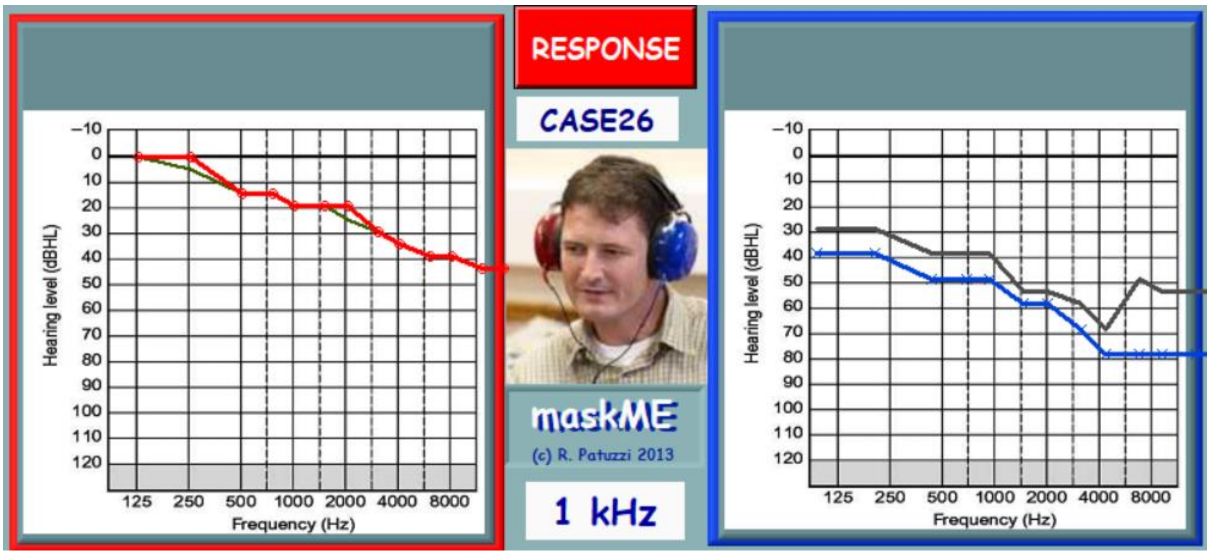
Please return this form to Anna.

Appendix D: maskME cases

A sample of three maskME cases as seen from the user perspective.







Appendix E: Learning outcomes and how each concept was addressed in each workbook and quiz

Learning outcomes											
		Workbook A		Workbook B		Workbook C		Workbook D		Workbook E	
		Group 1, Session 1		Group 2, Session 2		Group 3, Session 3		Group 6 , Session 4 (novices)		Groups 4 and 5, Session 4 (audiology students)	
Concept	**Understand**	**Workbook question (19 total)**	**Quiz A question number**	**Workbook question (13 total)**	**Quiz B question number**	**Workbook question (15 total)**	**Quiz C question number**	**Workbook question**	**Quiz C question number (9 total questions)**	**Workbook question**	**Quiz C question number (9 total questions)**
Interaural attenuation	The amount of sound in dB that a sound is attenuated as it travels from one cochlea to the other.	1, 2, 3, 4, 5, 6, 7	2	1, 2, 3, 4, 5	1	1, 2, 3, 4, 5	1	1, 2, 3, 4, 5	1	1, 2, 3, 4, 5	1
Cross over	Amount of sound from the test signal that is physically present in the non-test ear. May or may not be audible depending on threshold in non-test ear.	17, 18, 19	Case A, Case B, Case C	No specific question	Case-based Q1	No specific question	Case-based Q1	1, 2, 3, 4, 5	Case-based Q1	1, 2, 3, 4, 5	Case-based Q1
Cross-hearing	When the non-test ear hears the test signal before the test ear.	1, 2, 3, 4, 5, 7, 8, 16, 17, 18, 19	4, 6	1, 2, 3, 4, 5, 6, 13	No specific question	1, 2, 3, 4, 5, 6, 15	2	1, 2, 3, 4, 5	2	1, 2, 3, 4, 5	2
Purpose of masking	Isolate the ears and get ear-specific information.	No specific question	1	No specific question	No specific question	No specific question	No specific question	No specific question	No specific question	No specific question	No specific question
Shadow curves	Are the unmasked air-conduction thresholds from the poorer hearing ear which mimic the bone conduction thresholds from the better hearing ear	2, 3, 4	Case A, Case B, Case C	2, 3, 4	Case-based Q1	2, 3, 4	Case-based Q2	2, 3, 4	Case-based Q2	2, 3, 4	Case-based Q2
The effect of interaural attenuation size on plateau width	A larger interaural attenuation value means the plateau width will be wider.	10, 13, 17, 18	6, 12	7	7a	9	7a	9	7a	9	7a
Occlusion effect	Blocking the ear canal traps sound in that would normally escape, resulting in a louder sound being heard because there is more vibration in the skull/cochlea(s).	16	8, 9, 10	13	4, 5, 6	15	6a, 6b	15	6a, 6b	15	6a, 6b
The effect of the occlusion effect on plateau width	More masking noise is needed to 'cover' the increase in sound at the cochlea. More masking noise results in overmasking happens sooner which leads to a shorter plateau width.	No specific question	12	No specific question	7c	No specific question	7c	15	7c	15	7c
The effect of conductive component size on plateau width	More masking noise is needed to overcome the conductive component and reach the cochlea at the desired level. More masking noise results in overmasking happens sooner which leads to a shorter plateau width.	9, 10, 11, 12, 13, 14, 15	12	8, 9, 10, 11, 12	7b	10, 11	7b	10	7b	10	7b
The plateau	The test ear is responding at its threshold with the non-test ear sufficiently 'distracted' by masking noise.	7, 8, 9, 10, 11, 12, 13, 14, 15	3	6, 7, 8, 9, 10, 11, 12	2	6, 7, 8, 9, 10, 11, 12, 13	3	6, 7, 8, 9, 10, 11, 12, 13, 14	3	6, 7, 8, 9, 10, 11, 12, 13, 14	3
Undermasking	Not enough masking noise to reduce non-test ear cochlea contribution to responding to test tones	No specific question	No specific question	No specific question	No specific question	No specific question	No specific question	No specific question	No specific question	No specific question	No specific question
Overmasking	Masking noise is intense/strong/loud enough to be heard in the test ear and interferes with test ear ability to detect test signal at its true threshold. The test ear's threshold will appear worse than really is	7, 14, 15, 19	5	6, 7, 8, 9,	3	9, 10, 11, 13	4, 5	6, 9, 10, 11, 15	4, 5	6, 9, 10, 11, 15	4, 5
Masking dilemma	When overmasking happens immediately: the amount of masking needed in the non-test ear is enough to be heard by the test ear. Cannot get a plateau. Cannot get masked threhsolds. Cannot get accurate results from test ear. Often happens with conductive components or with a large asymmetry in hearing.	9, 11, 13	11	7, 8, 10, 12	Case-based Q2	Not taught in this session	Not taught in this session	11	No specific question	11	No specific question
Speech masking	Masking for speech stimuli is not done on a frequency-by-frequency basis as speech is a broadband signal. All bone conduction thresholds must be considered when analysing the audiogram for potential cross-hearing	17, 18, 19	7, Case D	Not taught in this session		Not taught in this session	Not taught in this session	Not taught in this session	Not taught in this session	Not taught in this session	Not taught in this session

Appendix F: Session structure and timing

Session 1: year 2 audiology students (Group 1, n=9). 1.30pm - 3.30pm						
Part of session		**Planned time to start part of session**	**Actual time started**	**Planned duration of part of session (minutes)**	**Actual duration of part of session (minutes)**	**Actual duration - estimated duration**
	Start class - welcome and give overview	1.30pm	1.30pm	2	3	1
	Quiz A	1.32pm	1.33pm	18	17	-1
Part 1	Part 1 talk: interaural attenuation and cross-hearing	1.50pm	1.50pm	8	4	-4
	maskME demonstration	1.58pm	1.54pm	7	3.5	-4
	Workbook questions 1-5 (interaural attenuation and cross-hearing for air conduction and shadow curves)	2.05pm	2pm	10	9	-1
	Shadow curves talk	2.15pm	2.09pm	5	2	-3
	Workbook questions 5 and 6 (interaural attenuation and cross-hearing for bone conduction) and review answers	2.20pm	2.11pm	2	9.15	7
	Break	2.30pm	2.20pm	10	8	-2
Part 2	Part 2 talk: doing masking, the plateau curve (undermasking, the plateau and overmasking)	2.40pm	2.28pm	5	5	0
	Workbook questions 7-15 (doing masking in maskME and plotting plateaus on maskME and on paper in a variety of conditions to see the effects of conductive components, hearing loss configurations and the effect of changing interaural attenuation)	2.45pm	2.33pm	15	22	7
	Review answers	3pm	2.55pm	2	1	-1
	Occlusion effect talk and workbook question 16 on the occlusion effect	3.02pm	2.56pm	5	6	1
	Speech masking talk and workbook questions 17-19	3.07pm	3.02pm	3	6	3
	Repeat Quiz A and complete Questionnaire A	3.10pm	3.08pm	20	13-26	-7 to +6

Session 2: year 1 audiology students (Group 2, n=10). 1pm - 3pm						
Part of session		**Planned time to start part of session**	**Actual time started**	**Planned duration of part of session (minutes)**	**Actual duration of part of session (minutes)**	**Actual duration - estimated duration**
	Start class - welcome and give overview	1pm	12.58pm	2	2	0
	Quiz B	1.02pm	1.03pm	20	21	1
Part 1	Part 1 talk: interaural attenuation and cross-hearing	1.22pm	1.24pm	6	4	-2
	maskME demonstration	1.28pm	1.28pm	5	3	-2
	Workbook questions 1-4 (interaural attenuation and cross-hearing for air conduction and shadow curves) and review answers	1.32pm	1.31pm	10	10	0
	Shadow curves talk	1.42pm	1.41pm	3	2	-1
	Workbook question 5 (interaural attenuation and cross-hearing for bone conduction) and review answers	1.45pm	1.43pm	5	4	-1
	Break	1.50pm	1.47pm	10	10	0
Part 2	Part 2 talk: doing masking, the plateau curve (undermasking, the plateau and overmasking)	2pm	1.57pm	5	5	0
	Workbook questions 6-12 (doing masking in maskME and plotting plateaus on maskME and on paper in a variety of conditions to see the effects of conductive components, hearing loss configurations and the effect of changing interaural attenuation) and review answers	2.05pm	2.03pm	20	27	7
	Occlusion effect talk, workbook question 13 on the occlusion effect and revie	2.25pm	2.30pm	9	10	1
	Repeat Quiz B and complete Questionnaire A	2.30pm	2.40pm	30	20	-10

Session 3: non-audiology students (Group 3, n=4). 9am - 12pm						
Part of session		**Planned time to start part of session**	**Actual time started**	**Planned duration of part of session (minutes)**	**Actual duration of part of session (minutes)**	**Actual duration - estimated duration**
	Start class - welcome and give overview	9am	9.05am	1	1	0
	Introduction to hearing talk	9.01am	9.07am	20	13	-7
Part 1	Part 1 talk: interaural attenuation and cross-hearing	9.35am	9.20am	3	5	2
	maskME demonstration and guide through workbook question 1	9.38am	9.25am	3	12	9
	Workbook questions 2-4 (interaural attenuation and cross-hearing for air conduction and shadow curves) and review answers	9.52am	9.37am	10	10	0
	Shadow curves talk	10.02am	9.47am	6	2	-4
	Workbook question 5 (interaural attenuation and cross-hearing for bone conduction) and review answers	10.08am	9.49am	6	7	1
	Break	10.14am	9.56am	10	10	0
Part 2	Part 2 talk: doing masking, the plateau curve (undermasking, the plateau and overmasking) including workbook question 6 as a demonstration	10.25am	10.06am	15	13	-2
	Workbook questions 7-14 (doing masking in maskME and plotting plateaus on maskME and on paper in a variety of conditions to see the effects of conductive components, hearing loss configurations and the effect of changing interaural attenuation) and review answers	10.40am	10.20am	25	48	23
	Break	11.05am	11.08am	5	10	5
Part 2	Recap of concepts covered so far and occlusion effect talk	11.10am	11.18am	5	8	3
	Workbook question 15 on the occlusion effect and review answer	11.15am	11.26am	8	9	1
	Complete Quiz C and Questionnaire B	11.23am	11.35am	30	25	-5

Session 4 timeline: audiology students and non-audiology students (Groups 4, 5 & 6 n=24) 9.30am - 12.30pm						
Part of session - novices/all		**Planned time to start part of session**	**Actual time started**	**Planned duration of part of session (minutes)**	**Actual duration of part of session (minutes)**	**Actual duration - estimated duration**
	Start class - welcome and give overview	9.30am	9.36	5	2	-3
	Introduction to hearing talk for Group 6 / Quiz C for Groups 4 and 5	9.35am	9.38	20	17	-3
	Kahoots quiz	9.55am	9.51	9	9	0
	Break	10.04am	10.01	10	5	-5
Part 1	Part 1 talk: interaural attenuation and cross-hearing	10.14am	10.07	4	13	9
	maskME demonstration and guide through workbook question 1	10.18am	1030	4	4	0
	Workbook questions 2-4 (interaural attenuation and cross-hearing for air conduction and shadow curves) and review answers	10.22am	10.34	10	8	-2
	Shadow curves talk	10.32am	10.42	6	5	-1
	Workbook question 5 (interaural attenuation and cross-hearing for bone conduction) and review answers	10.38am	10.47	6	3	-3
	Break	10.44am	10.50am	10	10	0
Part 2	Part 2 talk: doing masking, the plateau curve (undermasking, the plateau and overmasking) including workbook question 6 as a demonstration	10.54am	11	16	14	-2
	Workbook questions 7-14 (doing masking in maskME and plotting plateaus on maskME and on paper in a variety of conditions to see the effects of conductive components, hearing loss configurations and the effect of changing	11.10am	11.14	35	34	-1
	Review answers	11.45am	11.48	2	5	3
	Break	11.47am	11.53	5	5	0
Part 2	Recap of concepts covered so far and occlusion effect talk	11.52am	11.58	7	8	1
	Workbook question 15 on the occlusion effect and review answer	11.59am	12.06	8	11	3
	Kahoots quiz 2	12.07am	12.17	10	5	-5
	Complete Quiz C and Questionnaire B	12.17am	12.22	30		

WORKBOOK A

Clinical masking workbook

Part 1: Interaural attenuation and cross-hearing

Part 2: Doing masking

Takeaway sheet

Intended learning outcomes

1. Understand the purpose of masking for pure tones and speech stimuli
2. Understand cross hearing and interaural attenuation
3. Understand shadow curves
4. Recognise undermasking, the plateau, and overmasking
5. Understand how the occlusion effect affects masking

Part 1. Interaural attenuation and cross-hearing

The two cochleas are connected by structures in the head. If a sound is intense enough in one ear, it can also be audible in the other ear.

When you're testing one ear, and the *other* ear responds first, cross-hearing is happening! This is problematic for testing.

Interaural attenuation is how much a sound is attenuated as it travels from one ear to the other through the skull. It depends on test stimuli (e.g. pitch/frequency) and transducer. For example, the bone conduction vibrator has an IA of 0dB, and IA for air-conduction transducers varies from 40-75dB.

A small IA (e.g. 0dB) means that 0dB of energy is lost between the cochleas; i.e. when one ear is given a 20dB pure tone sound, 20dB also arrives to the other cochlea.

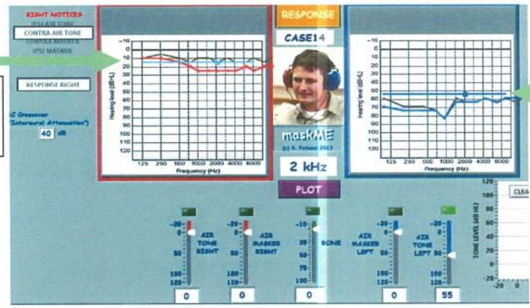
A large IA (e.g. 60dB) means that if one ear is presented with a 70dB pure tone sound, only 10dB of it

Example

1) Find the left ear's AC threshold at 2000Hz.

Use supra-aural headphones– IA is 40dB

Light blue line = level of crossover to non-test ear



Horizontal blue line = level of signal to test ear

Crossover is the portion of the signal from the test ear that physically reaches the non-test ear cochlea via interaural attenuation. It may or may not be heard, depending on how well the NTE can hear.

Cross-hearing is when the level at which the sound crosses over is *audible* in the NTE. The NTE cochlea must be sensitive enough to detect the crossed-over sound to be able to respond to it.

Cross-hearing is what we need to consider when doing hearing testing!

1. **Cross-hearing and IA**
Case 36 in maskME. Asymmetrical sensorineural hearing loss

No thresholds in the audiogram = no responses at all

Ask yourself: is there an obvious better ear? If one ear is much better than the other, it is possible that cross-hearing may occur.

a) Test the **right ear** air conduction threshold (using the Air Tone button) at 4000Hz.
What is the lowest level at which there is a response? ________________

b) Which ear is responding? Right/left

If the NTE responds before the TE, masking is required!

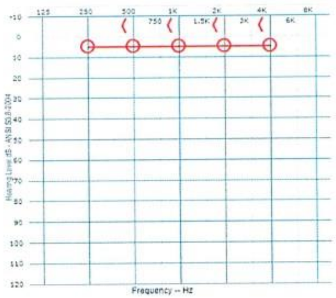
c) Test the **left ear** AC at 4000Hz. At what level is there a response (from either ear)?
____
Plot that on the audiogram below.

d) Which ear responds at this level? Right/left

e) What is the difference between the right ear bone conduction threshold and the level at which there is a response? ________________

f) How does this figure compare to the IA? ________________________________

g) Complete the unmasked left ear AC results for 500, 1000 and 2000Hz on the audiogram below.



Compare your answers with your neighbour

When do you need to mask air conduction thresholds?

____

____

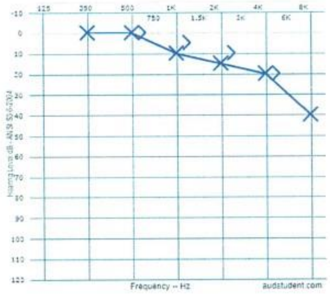
____

This is called the *shadow curve*: the unmasked left ear thresholds shadow the right ear BC thresholds.

Compare your shadow curves with your neighbour

Cross-hearing and IA
Shadow curves

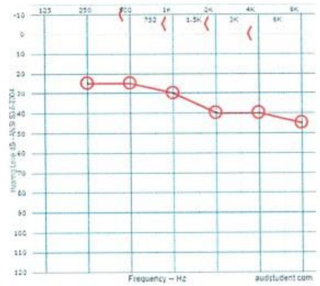
2. The right ear is completely dead. Draw where you find unmasked right AC thresholds on the audiogram below for 500, 1000, 2000 and 4000Hz.



Use supra-aural headphones– IA is 40dB

Case34 in maskME

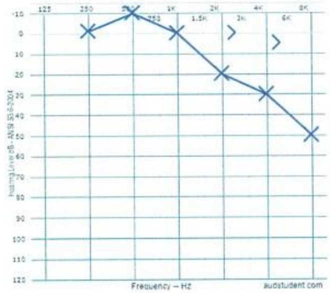
3. The left ear is completely dead. Draw where you find unmasked left AC thresholds for 500, 1000, 2000 and 4000Hz.



Use supra-aural headphones– IA is 40dB

Case09 in maskME

4. The right ear is completely dead. Draw where you find unmasked right AC thresholds for 500, 1000, 2000 and 4000Hz.



Use insert-earphones – IA is 60dB for all frequencies

Case07 in maskME

Cross-hearing and IA

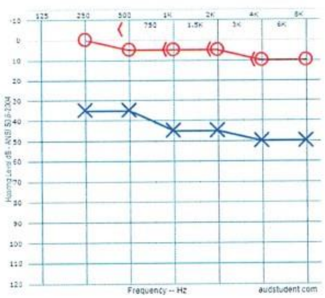
Shadow curves

Shadow curves happen when the sound to the bad ear is loud enough to overcome IA and be heard by the good ear.

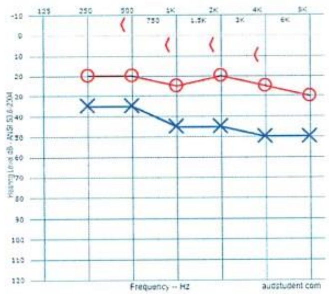
Shadow curves show cross-hearing! Not every situation with cross-hearing will have a shadow curve, but some do – so they're important to recognise.

They show unmasked AC thresholds of the *worse* ear and occur when there is a big difference between the two ears.

Example 1: right ear has normal hearing and left ear is totally dead



Example 2: right ear has a conductive hearing loss and left ear is totally dead



The left ear is showing a shadow curve, mimicking the shape of the right ear BC hearing thresholds.

The shadow curves for both examples are **exactly the same**, despite a difference in the right ear's AC thresholds.

NB: If the AC results are within normal limits, i.e. 15dB and better, BC testing is not usually done. Therefore, some shadow curves can appear to follow AC thresholds (if the AC thresholds are within normal limits).

Unmasked thresholds seen in shadow curves will likely need masking!

Interaural attenuation is a bone conduction mechanism: the difference in dB between the ears is mostly lost *through* the head, not around it (via the air).

Q) Do shadow curves mimic the bone conduction thresholds or air conduction thresholds of the better ear? ___________

5. **Bone conduction audiometry**

Cross-hearing and IA
Case 04. Symmetrical sloping sensorineural hearing loss

IA for the bone conduction vibrator is 0dB – but you **don't** need to change the IA figure in maskME

Ask yourself: is there an obvious better ear? Therefore, is cross-hearing likely to occur?

a) Test the right ear **bone conduction** thresholds at 500, 1500 and 3000Hz

b) Does cross-hearing occur? i.e. does the left ear respond before the right ear at any of those frequencies? Yes/no

c) Is masking needed for any of those frequencies in the right ear? If so, which one/s?

___

___

6. **Bone conduction audiometry**

Cross-hearing and IA
Case 01. Asymmetrical sensorineural hearing loss

a) Test the left ear BC threshold at 1000Hz. At what level is there a response? __________

b) What ear is responding at that level? Right/left

c) What is the true left ear's BC threshold at 1000Hz? ___________

d) Test the right ear bone conduction at 1000Hz. At what level is there a response?

____

e) What is the difference between the left and right unmasked bone conduction thresholds?

____

IA for the bone-conduction vibrator is 0dB! This means that you can present 50dB signal to the right ear and the left ear will also detect a 50dB signal.

Part 2: Doing masking and the plateau

When you're testing one ear, and the *other* ear responds first, cross-hearing is happening! When this happens, we can put masking noise into the better ear so that it is less likely or unable to respond to sounds presented to the test ear.

During masking, both the masking noise level and the signal level are varied. The masking noise raises the threshold (making it worse) of the non-test ear, decreasing the possibility of cross-hearing.

Hood (1957) realised that when the response is coming from the test ear cochlea, the response level is unchanged even if the masking intensity *is* changed. The **plateau** shows when this happens.

At this point, the masking noise has sufficiently raised the threshold of the non-test ear and reduced its ability to respond to sound presented to the test ear.

There are three stages of the plateau curve: undermasking, the plateau, and overmasking. Clinically, we aim to start with a masking noise that will be at the beginning of the plateau.

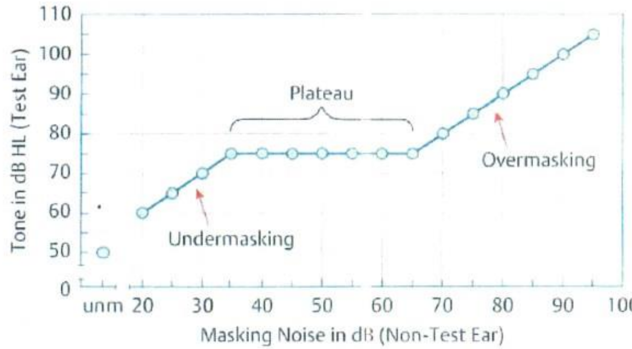


Image from Gelfand 2015 p.260

Undermasking	Plateau	Overmasking
Reponses are from NTE Not enough masking noise to elevate the NTE threshold	Reponses are from TE at true threshold Masking sound is sufficiently strong to elevate NTE threshold, and eliminate its ability to respond to signals to the TE	Responses are from TE but not at true threshold Masking sound is intense enough to cross-over and be audible in the TE, raising its threshold t detect the test signal

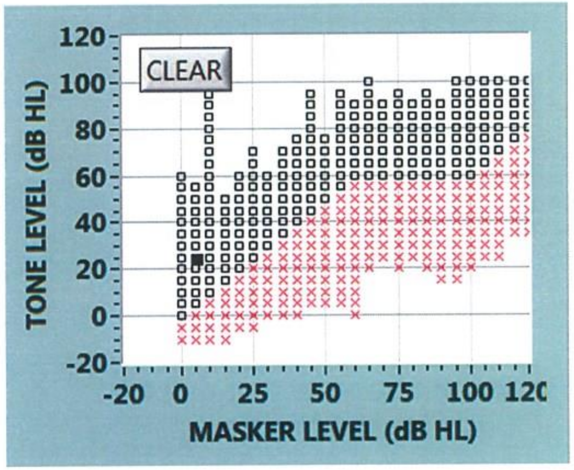
The plateau in maskME

Class demonstration – Case 01, testing the left ear BC at 2000Hz

□ indicates a response – but could be from either ear

X indicates *no* response from either ear

Tone to test ear



Masking sound to non-test ear – the better ear

The plateau curve shows us that the test ear's true threshold is at 60dB.

The plateau in this example is 30dB wide before overmasking occurs. Once a 20dB plateau has been reached, the threshold can be accepted.

In some cases, such as for conductive hearing losses, a plateau of 15dB can be accepted.

7. AC masking and the plateau
Case 14. Asymmetrical sensorineural hearing loss

Use supra-aural headphones– IA is 40dB

a) Test the left ear AC at 2000Hz. What level does cross-hearing happen at? ____________

b) What is the right ear's bone conduction threshold at 2000Hz? ____________

c) What is the difference between these two values? ____________

d) How does this compare to the IA? ____________

e) Now turn on the right air masking button. How loud do you have to make the masking noise to stop the cross-hearing response? ____________

Use the plateau plotter in maskME for the following activity PLOT

f) Increase the level of the left AC tone until there is a response and use the Plot button to plot each point, even if it is a non-response.

Every time the left ear responds, increase the masking noise by 10dB. Plot each point.

Every time the right ear responds, increase the AC tone by 5dB. Plot each point.

Continue to plot responses and non-responses until you have been able to obtain a 20dB plateau.

This masking procedure is called the Hood Procedure.

g) What is the left ear's true AC threshold at 2000Hz? ____________

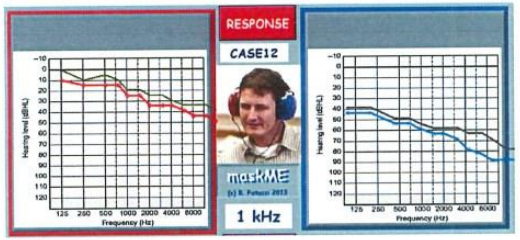
h) Continue to increase the masking noise and tone level and plot the results. What happens after the plateau?

____

____

Overmasking occurs when the masking noise is audible in the TE cochlea, raising its threshold, and interfering with its ability to respond at its true threshold.

8. Case 12
Air conduction masking



Use supra-aural headphones– IA is 40dB

a) Test the left ear's AC threshold at 4000Hz. Does the first response come from the left or right ear? Right/left

b) Is cross-hearing occurring? Yes/no

c) Start masking at 45dB and plot responses on the plateau plotter

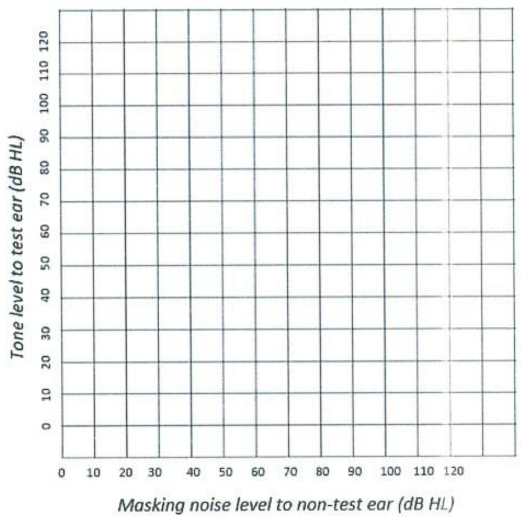
d) What is the left ear's AC masked threshold at 4000Hz? ___________

e) How wide is the plateau? _________

9. AC masking, the plateau and a dilemma
Case 06

Use supra-aural headphones– IA is 40dB

1. Test the right ear AC threshold at 2000Hz and mark responses and non-responses on the chart
2. Start masking at 65dB
3. Plot at least 8 points



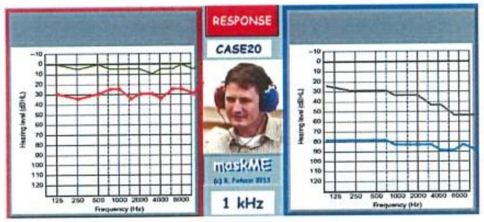
Use a tick for a response, and a cross for a non-response

This is known as a **masking dilemma**. This occurs when the minimum amount of masking needed in the non-test ear is strong enough to be audible in the test ear, resulting in overmasking happening immediately.

This can shorten the plateau, or even mean there is no plateau in some cases.

10. **Masking bone conduction thresholds and the plateau**

Case 20



a) Ensure IA is set to 40dB for supra-aural headphones.

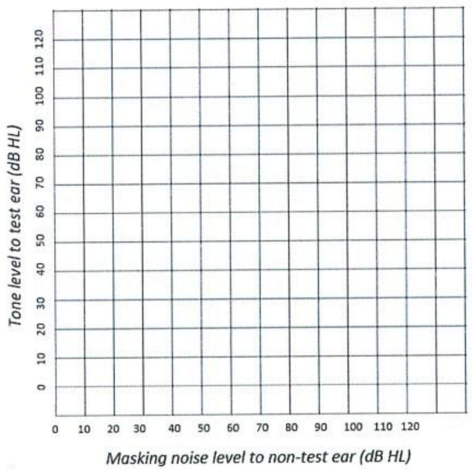
Test the left ear BC threshold at 1000Hz and plot the plateau curve until you reach the limits of the audiometer.

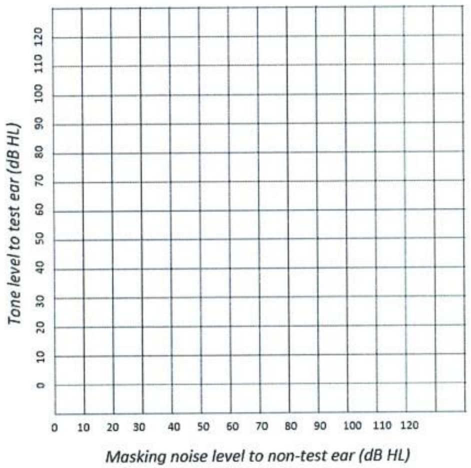
Start masking at 45dB

b) Change IA to 60dB for insert-earphones

Test the left ear BC threshold at 1000Hz and plot the plateau curve until you reach the limits of the audiometer.

Start masking at 45dB



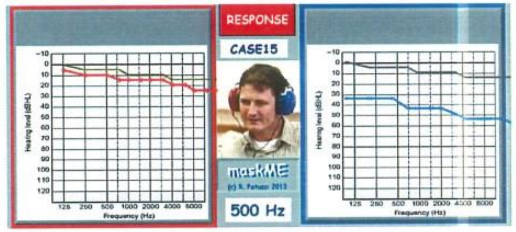


c) What happens to the plateau width when the interaural attenuation is bigger?

____

____

11. **Masking bone conduction, conductive components and the masking dilemma**
Case 15: unilateral conductive hearing loss



Use supra-aural headphones– IA is 40dB

Use the plateau plotter in maskME for this activity

Test the left ear bone conduction at 500Hz.

Start masking at 40dB.

a) Were you able to get a plateau? If so, how wide was it? ____________________

12. **Case 13: mild bilateral conductive hearing loss**

Use supra-aural headphones– IA is 40dB

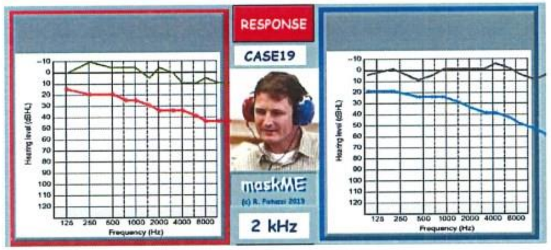
Use the plateau plotter in maskME for this activity

Test the right ear bone conduction at 4000Hz.

Start masking at 35dB.

a) Were you able to get a plateau? If so, how wide was it? ____________________

13. **Masking bone conduction, the plateau and the masking dilemma**
Case 19



a) Ensure IA is set to 40dB for supra-aural headphones.

Test the left ear BC threshold at 1000Hz and plot the plateau curve until you reach the limits of the audiometer.

Start masking at 45dB

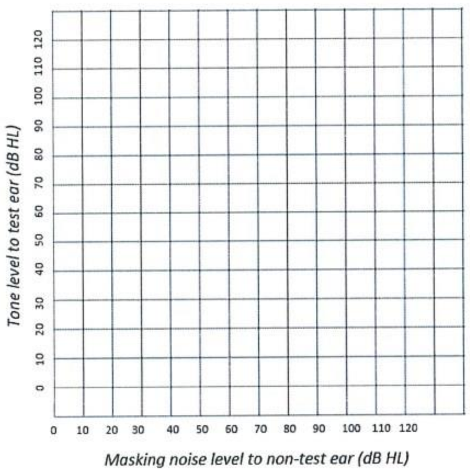
See if you can get a short 15dB plateau

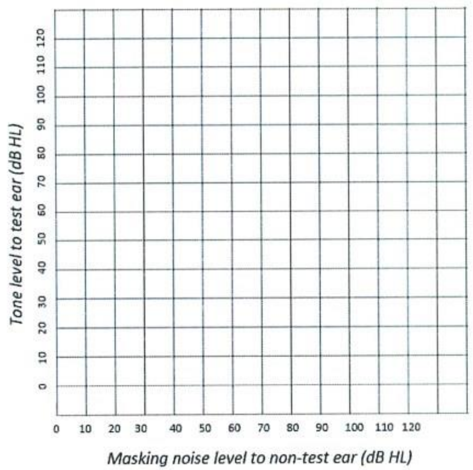
b) Change IA to 60dB for insert-earphones

Test the left ear BC threshold at 1000Hz and plot the plateau curve until you reach the limits of the audiometer.

Start masking at 45dB

See if you can get a short 15dB plateau





c) Is it possible to get a 15dB plateau in either situation? Yes/no. If so, using which transducer? Supra-aural headphones / insert earphones?

d) What configurations of hearing loss can lead to masking dilemmas? List two.

1. ______________________

2. ______________________

Masking BC and conductive components

Use supra-aural headphones– IA is 40dB

14. **Case 32**

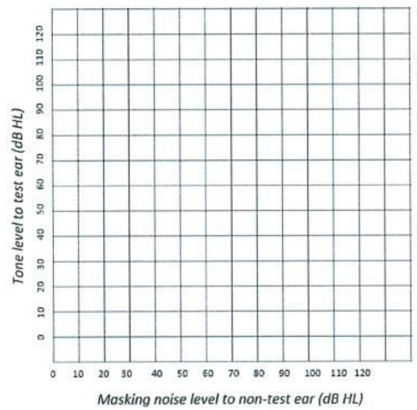
a) How large is the conductive component in the right ear at 500Hz?

____

Find the unmasked left BC threshold at 500Hz and mark it on the chart below.

Start masking at 30dB in the right ear and plot the plateau curve.

Plot two points of overmasking



b) How big (in dB) is the plateau before overmasking starts? __________

15. **Case 33**

a) How large is the conductive component in the right ear at 500Hz?

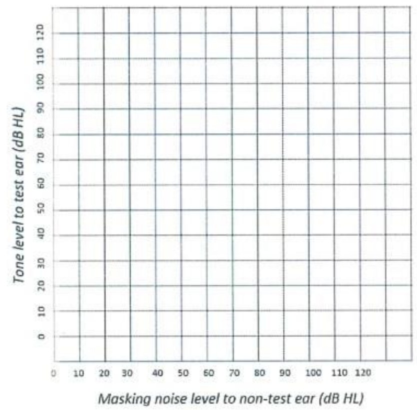
____

Find the unmasked left BC threshold at 500Hz and mark it on the chart below.

Start masking at 45dB in the non-test ear and plot the plateau curve.

More masking noise is required because the noise will be attenuated by the amount of the conductive component, but it still must reach the NTE cochlea at the same level as in Case 32.

Plot two points of overmasking



b) How big (in dB) is the plateau before overmasking starts? __________

15c) Larger conductive components in the non-test ear require more masking noise, which results in **shorter/longer/no change** plateaus that can be reached in the test ear.

15d) How much masking noise is needed to start effectively masking (at or near the beginning of the plateau) for bone conduction testing?

____

____

STOP HERE

The occlusion effect

Masking bone conduction and the occlusion effect

The occlusion effect (OE) occurs when one ear is occluded, like with a headphone on the non-test ear for masking. Occlusion stops leakage of sound out of ear canal, and traps extra sound energy in.

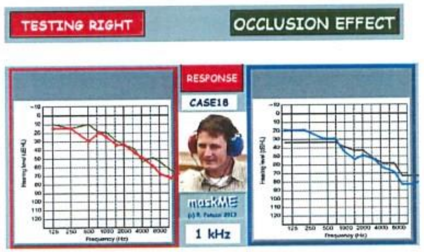
This leads to greater sound energy at the NTE cochlea, which sounds louder, too! This results in improved BC thresholds in an occluded ear (the NTE).

The OE is a problem during masked bone conduction testing because it increases the risk of cross-hearing.

Demonstration – the Bing test

maskME shows you how the OE looks:

Occlusion effect **off**



Occlusion effect **on**

Notice the difference in bone conduction thresholds in the non-test ear at 1000Hz and under.

Because the BC thresholds have improved in the NTE, cross-over happens at a lower level than without the OE on.

a) The OE for supra-aural headphones at 500Hz is 20dB. If a 500Hz pure-tone is presented to the test ear at 35dB, what level is it *actually* present at in the NTE cochlea? ____________

Masking noise presented to the NTE must be able to raise its threshold. Because the OE improves the NTE threshold, more masking noise is needed.

However, adding more masking noise increases the risk of overmasking!

16. Masking BC and the occlusion effect
Case 08

Use supra-aural headphones– IA is 40dB

a) Test the left ear's BC threshold at 1000Hz. At what level is there a response? ____________

b) Which ear is responding to this? ____________

c) What is the non-test ear's 500Hz BC threshold, without the OE turned on? And what does it change to after the OE is turned on?

With OE off: ____________________

With OE on: ____________________

The OE only occurs during masked bone conduction testing because in air-conduction testing, both ears are occluded and the effect is calibrated into the audiometer.

The OE is greater with supra-aural headphones than insert earphones, as supra-aural headphones physically vibrate the skull more, resulting in more energy at the cochlea.

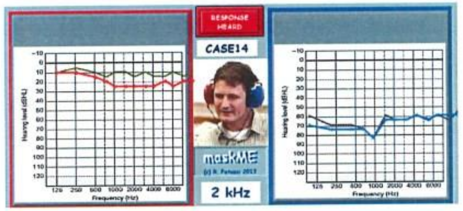
Insert earphones vibrate the skull less, as they are physically smaller. The deeper insert earphones are inserted (especially if they are inserted past the superficial cartilaginous portion of the ear canal), the less OE there is.

Speech testing and masking

Cross-hearing can also happen when we test a person's ability to discriminate speech sounds. We often present words at a level above (i.e. louder than) a person's threshold to get their maximum score. In clinical audiometry, we only present speech via air conduction.

Making the words louder means that they will also be louder on the other side of the head and may be audible in the NTE.

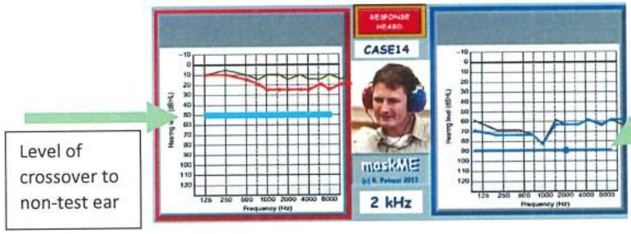
Example: get left ear's maximum speech score (PI max)



Use supra-aural headphones– IA is 40dB

Because speech is a broadband signal (i.e. covers more than just one frequency), you need to check if *any* of the **BC** thresholds in the right ear are good enough to be able to detect the portion of the signal that crosses over.

e.g. if you present the words at 90dB, the speech stimuli crosses over at 40dB into the right ear.



The light blue line is now below the thresholds of the right ear – meaning that the right ear is more than able to hear the sounds presented to the other ear. This indicates a need for masking to test the left ear alone.

There is no plateau-seeking during speech masking as we usually don't do threshold seeking.

17. **Case 18: symmetrical sensorineural hearing loss**

Speech masking

Use supra-aural headphones– IA is 40dB

Use the Air Tone slider at any frequency to see where cross-over occurs

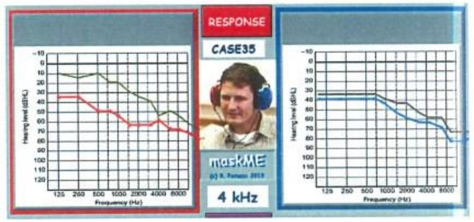
a) For the right ear, if you present the words at 50dB, what level does cross-over occur at in the left cochlea? ____________

b) Are there any left ear *bone conduction* thresholds at, or better than, this level? Yes/no

If there are any bone conduction thresholds at, or better than, the level of cross-over, masking noise will be needed.

c) For the left ear, speech would be presented at 50dB.
Would you need to mask the right ear? Yes/no

c) **Case 35. Same BC thresholds as Case 18 but with a conductive element bilaterally**



IA for supra-aural headphones is 40dB

IA for insert-earphones is 50dB (for speech)

d) Speech stimuli now needs to be more intense to get through the conductive component. If speech was presented at 80dB through supra-aural headphones, what level would it cross-over at in the left ear? ____________________

e) Would masking be needed? Yes/no

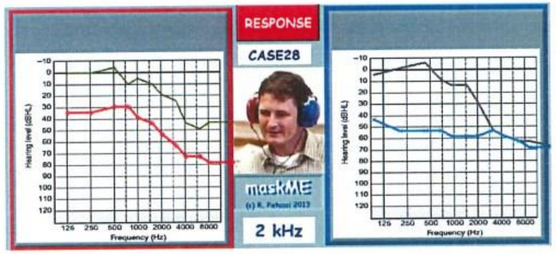
Stronger presentation levels for both speech stimuli and pure-tones are louder in the NTE and could be audible, depending on the NTE's BC thresholds.

When is masking required for speech testing?

____

____

18. Case 28. Bilateral conductive hearing loss
Speech masking



IA for supra-aural headphones is 40dB

IA for insert-earphones is 50dB (for speech)

The greater the IA, the more "separated" the ears are

a) For the right ear, using supra-aural headphones, if you present the speech sounds at 75dB, what level does cross-over occur at in the left cochlea? ______________

b) Are there any bone conduction thresholds in the left ear that are equal to or better than the cross-over level? Yes/no

c) Using insert-earphones (IA of 50dB), what level does this cross-over at in the left cochlea? ____________

d) Does cross-hearing occur in this situation if insert earphones are used? Yes/no

e) Why is the occlusion effect not accounted for when masking speech stimuli?

____

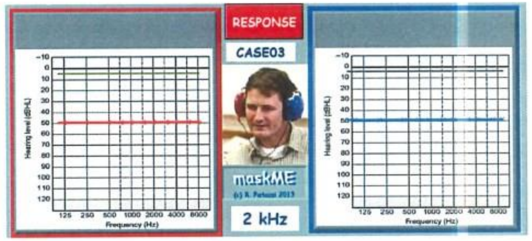
____

f) How much masking noise is needed to raise the threshold of the NTE?

____

____

19. Case 03. Bilateral conductive hearing loss
Speech masking



Use insert earphones – IA for speech stimuli is 50dB

a) For the left ear, speech sounds are presented at 70dB to try and get the best possible score. What level does this cross over at into the right cochlea? __________

b) Is there a risk of cross hearing? Yes/no

c) To mask the right ear, at least 95dB of masking noise is needed
IA for the speech masking noise is 50dB. How much of the masking noise would be present in the left ear (the test ear)? __________

d) Is that crossed-over masking noise *audible* to the left cochlea? Yes/no

e) Will the masking noise that has crossed over from the NTE to the TE impact the person's ability to discriminate speech sounds? Yes/no

Cases of bilateral conductive hearing loss are difficult to mask for both pure-tone stimuli *and* speech stimuli – and sometimes impossible. Make a note on the audiogram if this happens, e.g. *"Could not mask" or "Overmasking", or "Insufficient masking available"*.

Masking – takeaway points

The **purpose** of masking is to get accurate ear-specific information. Masking is the process of presenting a 'white' noise into the non-test ear and varying the level until responses are reliably only coming from the test ear.

Interaural attenuation is the reduction in the amount of skull vibration as sound travels from one cochlea to the other, through the skull via bone conduction mechanisms. IA varies depending on transducer type and type of sound (e.g. pure tone, masking noise, or speech stimuli).

Crossover is the portion of the signal from the test ear that physically reaches the non-test ear (NTE) via interaural attenuation. It may or may not be heard, depending on how well the NTE can hear.

Cross-hearing is when the level at which the sound crosses over is *audible* in the NTE. The NTE cochlea must be sensitive enough to detect the crossed-over sound to be able to respond to it. When cross-hearing is suspected, masked thresholds must be sought.

Air conduction thresholds are masked on a frequency-by-frequency basis when cross-hearing is suspected. It is important to look at the difference in dB between the ears at each frequency, looking for differences of IA or greater. It is particularly important to look at the bone conduction threshold of the better ear and compare it to the air conduction threshold of the worse ear. Compare between air conduction thresholds at each frequency as well as the AC of one ear and BC of the other.

Bone conduction thresholds are masked based on the presence of an air-bone gap of 15dB or more. Masked thresholds will determine whether the ABG represents a true conductive component in the test ear, or if the unmasked bone conduction threshold is coming from the other ear.

A masking **plateau** is reached when increases in masker level do not affect the test ear's ability to respond to the signal at a particular level. This level can be accepted as the test ear's masked threshold once an increase of 20dB in masker noise does not affect the responses. In some situations (e.g. bilateral conductive hearing loss), a plateau of 15dB can be accepted.

The **occlusion effect** occurs when an ear is occluded (e.g. with a headphone on the NTE for masking) and traps more sound in the ear canal. This leads to greater sound energy at the cochlea, which is perceived as a louder sound. This results in BC results appearing better than they are. It must be countered by adding more masking noise to the NTE, which then increases the risk of overmasking

Overmasking happens when the masking sound is strong enough to cross through the head and be heard by the test ear! It can make the test ear's thresholds appear worse than they actually are. Overmasking is most likely to happen in cases of conductive hearing loss.

Masking dilemmas occur when the amount of masking noise needed to effectively elevate the NTE's threshold is strong enough to cross the head and be audible in the test ear, resulting in an overmasking situation. They are most common with bilateral conductive losses, or one ear with a conductive loss and one ear with a sensorineural loss. It can be impossible to get masked thresholds in these situations.

Speech testing is masked when there is a possibility of cross-hearing. Unlike AC and BC testing, speech testing is not masked on a frequency by frequency basis: speech is a broadband signal and all bone conduction thresholds in the NTE must be considered! There is no plateau-seeking for masked speech testing in New Zealand.

Always ask yourself: is there any chance that the non-test ear can hear the sound presented to the test ear?

Clinical masking reading list

Gelfand's 2015 textbook, *Essentials of Audiology*, has a chapter on masking and is particularly easy to read.

Chaiklin, J. B. (1967). Inter aural attenuation and cross-hearing in air-conduction audiometry. *J aud res, 7*, 413-424.

Coles, R. R. A., and Priede, Vilija M. (1975). Masking of the non-test ear in speech audiometry. *Journal of Laryngology and Otology, 89*(3), 217-226. doi:10.1017/S0022215100080312

Gelfand, S. A. (2016). *Essentials of audiology* (Fourth ed.). New York: Thieme.

Hood, J. D. (1957). The principles and practice of bone conduction audiometry: a review of the present position. *Proceedings of the Royal Society of Medicine, 50*(9), 689.

Lidén, G., Liden, G., Nilsson, G., Nilsson, G., Anderson, H., & Anderson, H. (1959). Masking in clinical audiometry. *Acta Oto-Laryngologica, 50*(1-2), 125-136. doi:10.3109/00016485909129175

Martin, F. N. (1980). The Masking Plateau Revisited. *EAR AND HEARING, 1*(2), 112-116. doi:10.1097/00003446-198003000-00013

Martin, F. N., & Blosser, D. (1970). Cross hearing—air conduction or bone conduction. *Psychonomic Science, 20*(4), 231-231. doi:10.3758/bf03329037

Martin, F. N., Clark, John Greer. (2015). *Introduction to audiology* (Twelfth ed.). Boston: Pearson.

Naunton, R. F. (1960). A Masking Dilemma in Bilateral Conduction Deafness. *Archives of Otolaryngology, 72*(6), 753-757. doi:10.1001/archotol.1960.00740010767008

Oshiro, L. T., Silveira, M. R. M. d., & Gil, D. (2012). Influence of transducer's type in bilateral conductive and mixed hearing loss masking. *Revista CEFAC, 14*(4), 635-640.

Studebaker, G. A. (1962). On masking in bone-conduction testing. *Journal of speech and hearing research, 5*, 215-227.

Studebaker, G. A. (1964). Clinical Masking of Air and Bone Conducted Stimuli. *The Journal of speech and hearing disorders, 29*, 23-35.

Studebaker, G. A. (1967). Clinical masking of the nontest ear. *Journal of Speech and Hearing Disorders, 32*(4), 360-371.

Tonndorf, J. (1966). Bone conduction. Studies in experimental animals. *Acta Oto-Laryngologica*, Suppl 213:211.

Yacullo, W. S. (2015). Handbook of clinical audiology. In J. Katz (Ed.), (Seventh ed.). Philadelphia: Wolters Kluwer Health.

WORKBOOK B

Clinical masking workbook

Intended learning outcomes

1. Understand the purpose of masking for pure tone stimuli
2. Understand cross hearing and interaural attenuation
3. Understand shadow curves
4. Recognise undermasking, the plateau, and overmasking
5. Understand how the occlusion effect affects masking

Part 1. Interaural attenuation and cross-hearing

The two cochleas are connected by structures in the head. If a sound is intense enough in one ear, it can also be audible in the other ear.

When you're testing one ear, and the *other* ear responds first, cross-hearing is happening! This is problematic for testing.

Interaural attenuation is how much a sound is attenuated as it travels from one ear to the other through the skull. It depends on test stimuli (e.g. pitch/frequency) and transducer. For example, the bone conduction vibrator has an IA of 0dB, and IA for air-conduction transducers varies from 40-75dB.

A small IA (e.g. 0dB) means that 0dB of energy is lost between the cochleas; i.e. when one ear is given a 20dB pure tone sound, 20dB also arrives to the other cochlea.

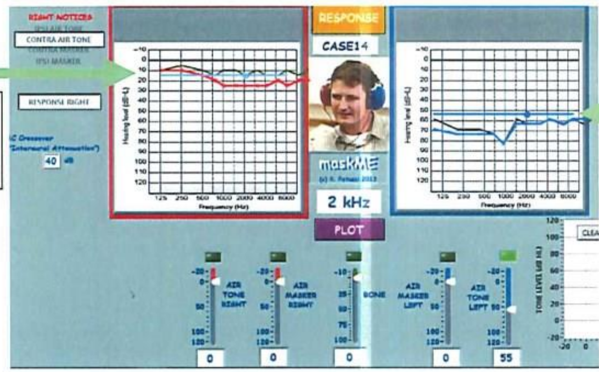
A large IA (e.g. 60dB) means that if one ear is presented with a 70dB pure tone sound, only 10dB of it

Example

1) Find the **left** ear's AC threshold at 2000Hz.

Use supra-aural headphones– IA is 40dB

Light blue line = level of crossover to non-test ear



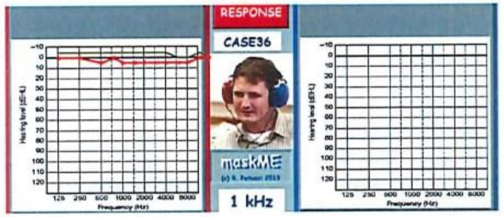
Horizontal blue line = level of signal to test ear

Crossover is the portion of the signal from the test ear that physically reaches the non-test ear cochlea via interaural attenuation. It may or may not be heard, depending on how well the NTE can hear.

Cross-hearing is when the level at which the sound crosses over is *audible* in the NTE. The NTE cochlea must be sensitive enough to detect the crossed-over sound to be able to respond to it.

Cross-hearing is what we need to consider when doing hearing testing!

1. **Cross-hearing and IA**
   Case 36 in maskME. Asymmetrical sensorineural hearing loss



No thresholds in the audiogram = no responses at all

Ask yourself: is there an obvious better ear? If one ear is much better than the other, it is possible that cross-hearing may occur.

a) Test the **right** ear air conduction threshold (using the Air Tone button) at 4000Hz. What is the lowest level at which there is a response? ________

b) Which ear is responding? Right/left

If the NTE responds before the TE, masking is required!

c) Test the **left** ear AC at 4000Hz. At what level is there a response (from either ear)?

____

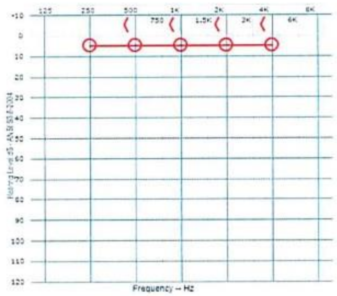
Plot that on the audiogram below.

d) Which ear responds at this level? Right/left

e) What is the difference between the right ear bone conduction threshold and the level at which there is a response? ________

f) How does this figure compare to the IA? ________

g) Complete the unmasked **left** ear AC results for 500, 1000 and 2000Hz on the audiogram below.



Compare your answers with your neighbour

When do you need to mask air conduction thresholds?

____

____

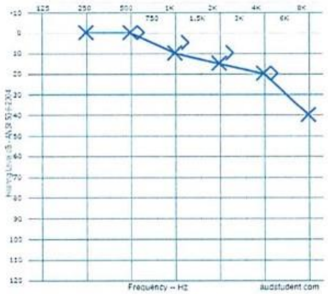
____

This is called the *shadow curve*: the unmasked left ear thresholds shadow the right ear BC thresholds.

Compare your shadow curves with your neighbour

Cross-hearing and IA
Shadow curves

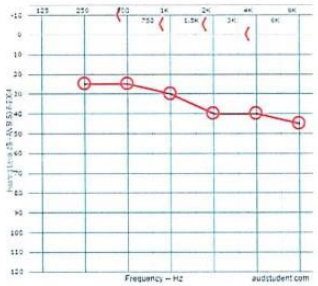
2. The right ear is completely dead. Draw where you find unmasked **right** AC thresholds on the audiogram below for 500, 1000, 2000 and 4000Hz.



Use supra-aural headphones– IA is 40dB

Case34 in maskME

3. The left ear is completely dead. Draw where you find unmasked **left** AC thresholds for 500, 1000, 2000 and 4000Hz.



Use supra-aural headphones– IA is 40dB

Case09 in maskME

4. The right ear is completely dead. Draw where you find unmasked **right** AC thresholds for 500, 1000, 2000 and 4000Hz.

Use insert-earphones – IA is 60dB for all frequencies

Case07 in maskME

Cross-hearing and IA

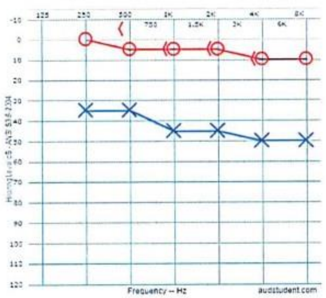
Shadow curves

Shadow curves happen when the sound to the bad ear is loud enough to overcome IA and be heard by the good ear.

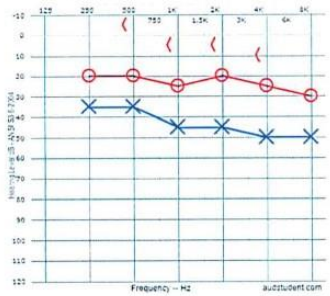
Shadow curves show cross-hearing! Not every situation with cross-hearing will have a shadow curve, but some do – so they're important to recognise.

They show unmasked AC thresholds of the *worse* ear and occur when there is a big difference between the two ears.

Example 1: right ear has normal hearing and left ear is totally dead



Example 2: right ear has a conductive hearing loss and left ear is totally dead



The left ear is showing a shadow curve, mimicking the shape of the right ear BC hearing thresholds.

The shadow curves for both examples are **exactly the same**, despite a difference in the right ear's AC thresholds.

NB: If the AC results are within normal limits, i.e. 15dB and better, BC testing is not usually done. Therefore, some shadow curves can appear to follow AC thresholds (if the AC thresholds are within normal limits).

Unmasked thresholds seen in shadow curves will likely need masking!

Interaural attenuation is a bone conduction mechanism: the difference in dB between the ears is mostly lost *through* the head, not around it (via the air).

Q) Do shadow curves mimic the **bone** conduction thresholds or **air** conduction thresholds of the better ear? ___________

5. **Bone conduction audiometry**

Cross-hearing and IA
Case 01. Asymmetrical sensorineural hearing loss

IA for the bone conduction vibrator is 0dB – but you **don't** need to change the IA figure in maskME

a) Test the **left** ear BC threshold at 1000Hz. At what level is there a response? __________

b) What ear is responding at that level? Right/left

c) What is the true **left** ear's BC threshold at 1000Hz? ___________

d) Test the **right** ear bone conduction at 1000Hz. At what level is there a response? ___________

e) When there is cross-hearing happening, what is the difference between the left and right unmasked bone conduction thresholds? ___________

IA for the bone-conduction vibrator is 0dB! This means that you can present 50dB signal to the right ear and the left ear will also detect a 50dB signal.

Part 2: Doing masking and the plateau

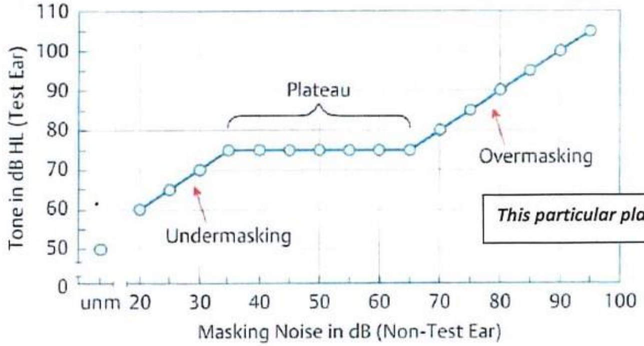
When you're testing one ear, and the *other* ear responds first, cross-hearing is happening! When this happens, we can put masking noise into the better ear so that it is less likely or unable to respond to sounds presented to the test ear.

During masking, both the masking noise level and the signal level are varied. The masking noise raises the threshold (making it worse) of the non-test ear, decreasing the possibility of cross-hearing.

Hood (1957) realised that when the response is coming from the test ear cochlea, the response level is unchanged even if the masking intensity *is* changed. This is the **plateau**.

At this point, the masking noise has sufficiently raised the threshold of the non-test ear and reduced its ability to respond to sound presented to the test ear.

There are three stages of the plateau curve: undermasking, the plateau, and overmasking. Clinically, we aim to start with a masking noise that will be at the beginning of the plateau.



This particular plateau is 30dB wide

Image from Gelfand 2015 p.260

Undermasking	Plateau	Overmasking
Reponses are from NTE Not enough masking noise to elevate the NTE threshold	Reponses are from TE at true threshold Masking sound is sufficiently strong to elevate NTE threshold, and eliminate its ability to respond to signals to the TE	Responses are from TE but not at true threshold Masking sound is intense enough to cross-over and be audible in the TE, raising its threshold to detect the test signal

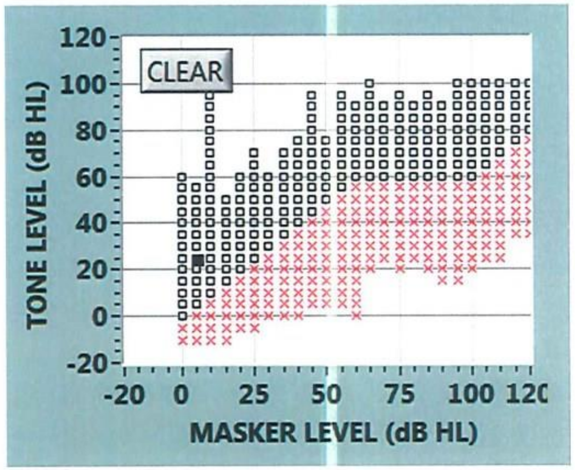
The plateau in maskME

Class demonstration – Case 01, testing the left ear BC at 2000Hz

☐ indicates a response – but could be from either ear

X indicates *no* response from either ear

Tone to test ear



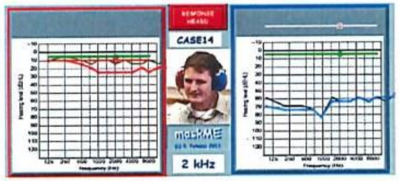
Masking sound to non-test ear – the better ear

The plateau curve shows us that the test ear's true threshold is at 60dB.

The plateau in this example is 30dB wide before overmasking occurs. Once a 20dB plateau has been reached, the threshold can be accepted.

In some cases, such as for conductive hearing losses, a plateau of 15dB can be accepted.

6. **AC masking and the plateau**
Case 14. Asymmetrical sensorineural hearing loss



Use supra-aural headphones– IA is 40dB

a) Test the **left** ear AC at 2000Hz. What level does cross-hearing happen at? ____________

b) What is the **right** ear's bone conduction threshold at 2000Hz? ____________

c) What is the difference between these two values? ____________

d) How does this compare to the IA? ______________________________________

Go back to testing the left ear AC and find its threshold again– turn off the bone conduction slider!

e) Now turn on the **right** air masking button. How loud do you have to make the masking noise to stop the cross-hearing response? ________________

Use the plateau plotter in maskME for the following activity PLOT

f) Increase the level of the left AC tone until there is a response and use the Plot button to plot each point, even if it is a non-response.

Every time the left ear responds, increase the masking noise by 10dB. Plot each point.

Every time the right ear responds, increase the AC tone by 5dB. Plot each point.

Continue to plot responses and non-responses until you have been able to obtain a 20dB plateau

This masking procedure is called the Hood Procedure.

g) What is the left ear's true AC threshold at 2000Hz? ____________

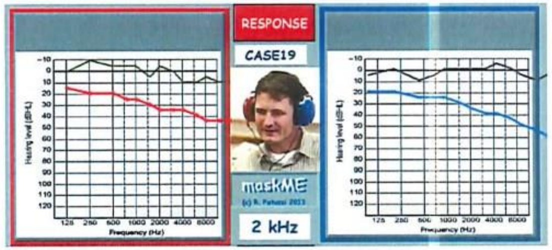
h) Continue to increase the masking noise and tone level and plot the results. What happens after the plateau?

____

____

Overmasking occurs when the masking noise is audible in the TE cochlea, raising its threshold, and interfering with its ability to respond at its true threshold.

7. **Masking bone conduction, the plateau and the masking dilemma**
Case 19



Use the plateau plotter in maskME for the following activities

a) Ensure IA is set to 40dB for supra-aural headphones.

Test the **left** ear BC threshold at 1000Hz and plot the plateau curve until you reach the limits of the audiometer.

Start masking at 45dB

b) How wide is the plateau? __________

c) At what masking level does overmasking start? __________

d) **Change IA to 60dB for insert-earphones**

Test the **left** ear BC threshold at 1000Hz and plot the plateau curve until you reach the limits of the audiometer.

Start masking at 45dB

e) How wide is the plateau? __________

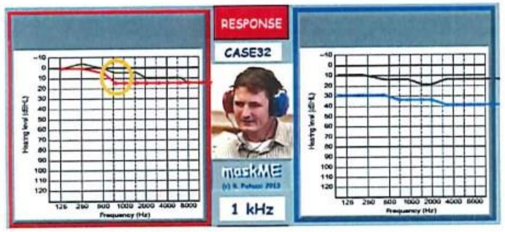
f) At what masking level does overmasking start? __________

d) Larger interaural attenuation values result **in longer/shorter/no different** plateau widths.

Extra cases for fast workers!

Masking BC and conductive components

8. Case 32



Use supra-aural headphones– IA is 40dB

a) How large is the conductive component in the **right** ear at 500Hz? ______________

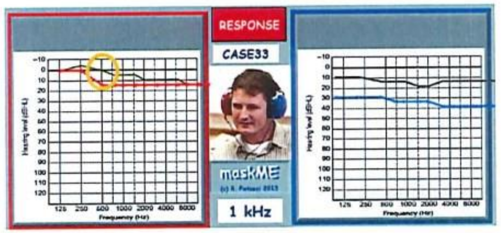
Find the unmasked **left** BC threshold at 500Hz and mark it on the chart below.

Start masking at 30dB in the right ear and plot the plateau curve.

Plot two points of overmasking

b) How big (in dB) is the plateau before overmasking starts? __________

9. Case 33



a) How large is the conductive component in the **right** ear at 500Hz? ______________

Find the unmasked **left** BC threshold at 500Hz and mark it on the chart below.

Start masking at 45dB in the non-test ear and plot the plateau curve.

More masking noise is required because the noise will be attenuated by the amount of the conductive component, but it still must reach the NTE cochlea at the same level as in Case 32.

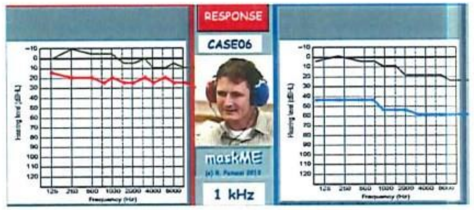
Plot two points of overmasking

b) How big (in dB) is the plateau before overmasking starts? __________

c) Larger conductive components result **in longer/shorter/no different** plateau widths.

Case 33 shows a **masking dilemma.** This occurs when the minimum amount of masking needed in the non-test ear is strong enough to be audible in the test ear, resulting in overmasking happening immediately. This can shorten the plateau, or even mean there is no plateau in some cases.

10. AC masking, the plateau and a dilemma
Case 06



Use supra-aural headphones– IA is 40dB

Use the plateau plotter in maskME for the following activity

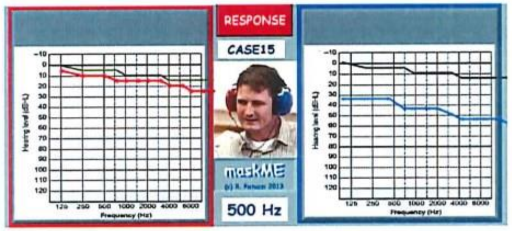
1. Test the **right** ear AC threshold at 2000Hz and mark responses and non-responses on the chart
2. Start masking in the **left** ear at 65dB
3. Plot at least 8 points
4. Are you able to get a plateau? If so, how wide is it?

____

____

Extra cases for fast workers!

11. **Masking bone conduction, conductive components and the masking dilemma**
    Case 15: unilateral conductive hearing loss



Use supra-aural headphones– IA is 40dB

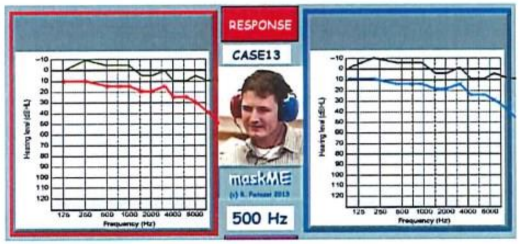
Use the plateau plotter in maskME for this activity

Test the **left** ear **bone** conduction at 500Hz.

Start the masking noise level at 40dB.

Were you able to get a plateau? If so, how wide was it? ____________________

12. **Case 13: mild bilateral conductive hearing loss**



Use supra-aural headphones– IA is 40dB

Use the plateau plotter in maskME for this activity

Test the **right** ear **bone** conduction at 4000Hz.

Start masking at 35dB.

Were you able to get a plateau? If so, how wide was it? ____________________

Compare your answers with your neighbour

The occlusion effect

Masking bone conduction and the occlusion effect

The occlusion effect (OE) occurs when one ear is occluded, like with a headphone on the non-test ear for masking. Occlusion stops leakage of sound out of ear canal, and traps extra sound energy in.

This leads to greater sound energy at the NTE cochlea, which sounds louder, too! This results in improved BC thresholds in an occluded ear (the NTE).

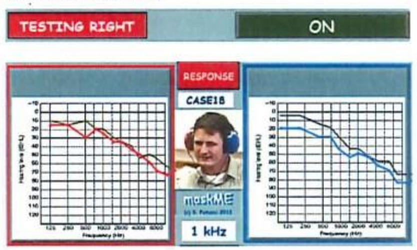
The OE is a problem during masked bone conduction testing because it increases the risk of cross-hearing.

Why does only the bone conduction threshold of the NTE change while masking?

maskME shows you how the OE looks:

Occlusion effect **off**

Occlusion effect **on**



Notice the difference in bone conduction thresholds in the non-test ear at 1000Hz and under.

Because the BC thresholds have improved in the NTE, cross-over happens at a lower level than without the OE on.

a) The OE for supra-aural headphones at 500Hz is 20dB. If a 500Hz pure-tone is presented to the test ear at 35dB, what level is it *actually* present at in the NTE cochlea? ____________

Masking noise presented to the NTE must be able to raise its threshold. Because the OE improves the NTE threshold, more masking noise is needed.

However, adding more masking noise increases the risk of overmasking!

13. Masking BC and the occlusion effect
Case 08

Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's BC threshold at 1000Hz. At what level is there a response? ____________

b) Which ear is responding to this with the OE button off? __________

c) Which ear is responding to this with the OE button on? __________

d) If the non-test ear is occluded, what does this mean for the likelihood of non-test ear cross-hearing?

____

____

e) What would this mean for the likelihood of overmasking?

____

____

The OE only occurs during masked bone conduction testing because in air-conduction testing, both ears are occluded and the effect is calibrated into the audiometer.

The OE is greater with supra-aural headphones than insert earphones, as supra-aural headphones physically vibrate the skull more, resulting in more energy at the cochlea.

Insert earphones vibrate the skull less, as they are physically smaller. The deeper insert earphones are inserted (especially if they are inserted past the superficial cartilaginous portion of the ear canal), the less OE there is.

Masking – takeaway points

The **purpose** of masking is to get accurate ear-specific information. Masking is the process of presenting a 'white' noise into the non-test ear and varying the level until responses are reliably only coming from the test ear.

Interaural attenuation is the reduction in the amount of skull vibration as sound travels from one cochlea to the other, through the skull via bone conduction mechanisms. IA varies depending on transducer type and type of sound (e.g. pure tone, masking noise, or speech stimuli).

Crossover is the portion of the signal from the test ear that physically reaches the non-test ear (NTE) via interaural attenuation. It may or may not be heard, depending on how well the NTE can hear.

Cross-hearing is when the level at which the sound crosses over is *audible* in the NTE. The NTE cochlea must be sensitive enough to detect the crossed-over sound to be able to respond to it. When cross-hearing is suspected, masked thresholds must be sought.

Air conduction thresholds are masked on a frequency-by-frequency basis when cross-hearing is suspected. It is important to look at the difference in dB between the ears at each frequency, looking for differences of IA or greater. It is particularly important to look at the bone conduction threshold of the better ear and compare it to the air conduction threshold of the worse ear. Compare between air conduction thresholds at each frequency as well as the AC of one ear and BC of the other.

Bone conduction thresholds are masked based on the presence of an air-bone gap of 15dB or more. Masked thresholds will determine whether the ABG represents a true conductive component in the test ear, or if the unmasked bone conduction threshold is coming from the other ear.

A masking **plateau** is reached when increases in masker level do not affect the test ear's ability to respond to the signal at a particular level. This level can be accepted as the test ear's masked threshold once an increase of 20dB in masker noise does not affect the responses. In some situations (e.g. bilateral conductive hearing loss), a plateau of 15dB can be accepted.

The **occlusion effect** occurs when an ear is occluded (e.g. with a headphone on the NTE for masking) and traps more sound in the ear canal. This leads to greater sound energy at the cochlea, which is perceived as a louder sound. This results in BC results appearing better than they are. It must be countered by adding more masking noise to the NTE, which then increases the risk of overmasking

Overmasking happens when the masking sound is strong enough to cross through the head and be heard by the test ear! It can make the test ear's thresholds appear worse than they actually are. Overmasking is most likely to happen in cases of conductive hearing loss.

Masking dilemmas occur when the amount of masking noise needed to effectively elevate the NTE's threshold is strong enough to cross the head and be audible in the test ear, resulting in an overmasking situation. They are most common with bilateral conductive losses, or one ear with a conductive loss and one ear with a sensorineural loss. It can be impossible to get masked thresholds in these situations.

Always ask yourself: is there any chance that the non-test ear can hear the sound presented to the test ear?

Clinical masking reading list

Gelfand's 2015 textbook, *Essentials of Audiology*, has a chapter on masking and is particularly easy to read.

Chaiklin, J. B. (1967). Inter aural attenuation and cross-hearing in air-conduction audiometry. *J aud res, 7*, 413-424.

Coles, R. R. A., and Priede, Vilija M. (1975). Masking of the non-test ear in speech audiometry. *Journal of Laryngology and Otology, 89*(3), 217-226. doi:10.1017/S0022215100080312

Gelfand, S. A. (2016). *Essentials of audiology* (Fourth ed.). New York: Thieme.

Hood, J. D. (1957). The principles and practice of bone conduction audiometry: a review of the present position. *Proceedings of the Royal Society of Medicine, 50*(9), 689.

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Martin, F. N., & Blosser, D. (1970). Cross hearing—air conduction or bone conduction. *Psychonomic Science, 20*(4), 231-231. doi:10.3758/bf03329037

Martin, F. N., Clark, John Greer. (2015). *Introduction to audiology* (Twelfth ed.). Boston: Pearson.

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Oshiro, L. T., Silveira, M. R. M. d., & Gil, D. (2012). Influence of transducer's type in bilateral conductive and mixed hearing loss masking. *Revista CEFAC, 14*(4), 635-640.

Studebaker, G. A. (1962). On masking in bone-conduction testing. *Journal of speech and hearing research, 5*, 215-227.

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Tonndorf, J. (1966). Bone conduction. Studies in experimental animals. *Acta Oto-Laryngologica*, Suppl 213:211.

Yacullo, W. S. (2015). Handbook of clinical audiology. In J. Katz (Ed.), (Seventh ed.). Philadelphia: Wolters Kluwer Health.

Clinical masking workbook

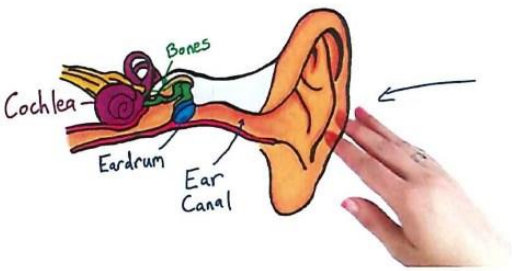
Part 1: Interaural attenuation and cross-hearing

Part 2: Doing masking

List of key terms

Intended learning outcomes

1. Understand interaural attenuation
2. Understand cross-hearing
3. Understand shadow curves
4. Understand the purpose of masking
5. Understand the plateau
6. Understand overmasking
7. Understand how the following affect plateau width
   -interaural attenuation
   -the occlusion effect
   -the size of conductive components



Part 1. Interaural attenuation and cross-hearing

The two cochleas are connected by structures in the head. If a sound is intense enough in one ear, it can also be audible in the other ear.

When you're testing one ear, and the *other* ear responds first, ***cross-hearing*** is happening! This is problematic for testing.

***Interaural attenuation* (IA) is how much a sound is attenuated as it travels from one ear to the other through the skull.** It depends on test stimuli (e.g. frequency) and transducer (speaker). For example, the bone conduction vibrator has an IA of 0dB, and IA for air-conduction transducers (supra-aural headphones and insert earphones) varies from 40-75dB.

A small IA (e.g. 0dB) means that 0dB of energy is lost between the cochleas; i.e. when one ear is given a 20dB pure tone sound, 20dB also arrives to the other cochlea.

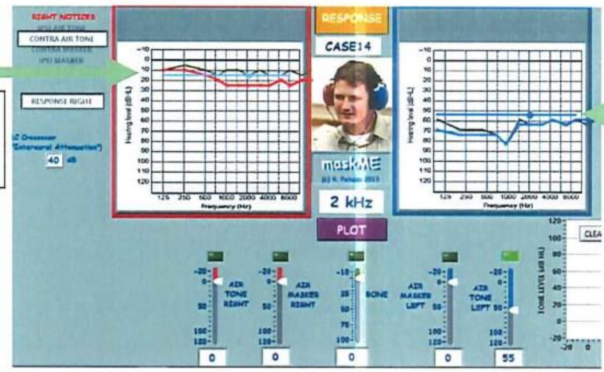
A large IA (e.g. 60dB) means that if one ear is presented with a 70dB pure tone sound, 60dB of it is lost in transmission between the cochleas, and only 10dB of it arrives at the other cochlea after passing through the skull.

<u>Example</u>

1) Find the **left** ear's air conduction threshold at 2000Hz. Use the Air Tone slider to find this out.

Use supra-aural headphones– IA is 40dB

Light blue line = level of crossover to non-test ear



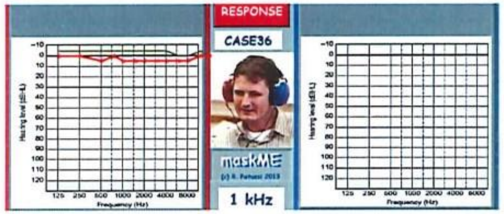
Horizontal blue line = level of signal to test ear

Crossover is the portion of the signal from the test ear that physically reaches the non-test ear cochlea via interaural attenuation. It may or may not be heard, depending on how well the non-test ear can hear.

Cross-hearing is when the level at which the sound crosses over is *audible* in the non-test ear . The non-test ear cochlea must be sensitive enough to detect the crossed-over sound to be able to respond to it.

Cross-hearing is what we need to consider when doing hearing testing!

1. **Cross-hearing and interaural attenuation**
   Case 36 in maskME. Right ear normal and dead left ear



No thresholds in the audiogram = no responses at all (i.e. dead ear!)

Ask yourself: is there an obvious better ear? If one ear is much better than the other, it is possible that cross-hearing may occur.

a) Test the **right** ear air conduction threshold (using the Air Tone slider) at 4000Hz. What is the lowest level (in dB) at which there is a response from either ear?

____

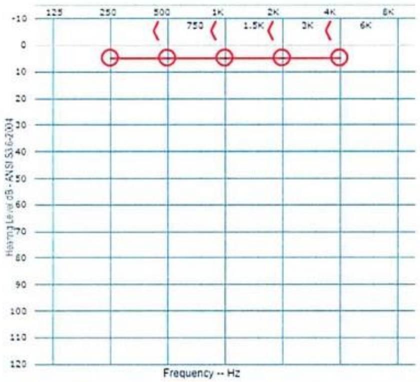
b) Which ear is responding? <u>Right/left</u>

c) Test the **left** ear air conduction threshold at 4000Hz. At what level is there a response (from either ear)? ____________
Plot that on the audiogram below using a cross symbol.

d) Which ear responds at this level? <u>Right/left</u>

If the non-test ear responds before the test ear, masking will be required to get separate ear information

e) Complete the **left** ear air conduction results for 500, 1000 and 2000Hz on the audiogram below. Use cross symbols.



Compare your answers with your neighbour

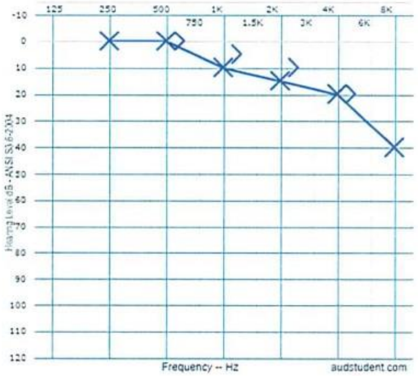
	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	I or □	>	]

This is called the *shadow curve*: the unmasked left ear thresholds shadow the right ear BC thresholds.

Cross-hearing and interaural attenuation
Shadow curves

2. Case 34 in maskME. The **right** ear is completely dead. Test the **right** ear's air conduction thresholds using the Air Tone slider for 500, 1000, 2000 and 4000Hz.

   Mark the quietest levels for each frequency where the response button lights up, *even if it is from the **left** ear.* Mark them with open circles.

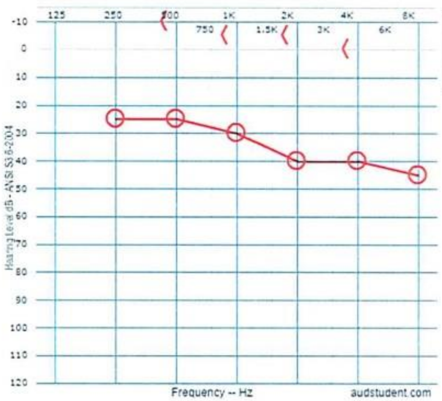


Use supra-aural headphones– IA is 40dB

	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	I or □	>	]

3. Case 09 in maskME. The **left** ear is completely dead. Test the **left** ear's air conduction thresholds using the Air Tone slider for 500, 1000, 2000 and 4000Hz.

Mark the quietest levels where the response button lights up, *even if it is from the **right** ear.* Mark them with crosses.



Use supra-aural headphones– IA is 40dB

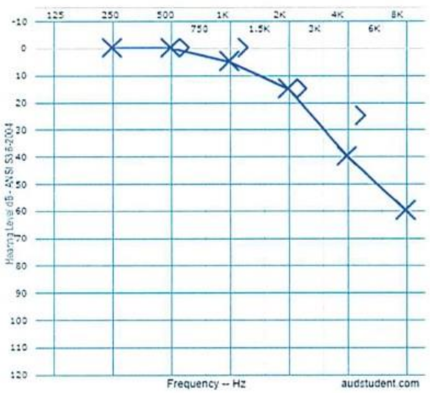
Compare your shadow curves with your neighbour

Compare your shadow curves with your neighbour

Cross-hearing and interaural attenuation
Shadow curves _continued_

4. Case 07 in maskME. The **right** ear is completely dead. Test the **right** ear's air conduction thresholds using the Air Tone slider for 500, 1000, 2000 and 4000Hz.

Mark the quietest levels where the response button lights up, *even if it is from the **left** ear.* Mark them with open circles.



Use insert-earphones – change the interaural attenuation to 60dB

	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	⌶ or □	>	]

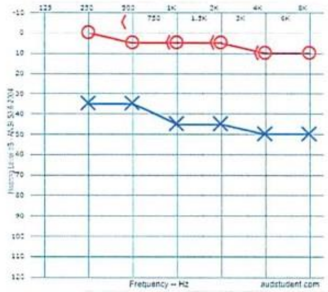
Cross-hearing and interaural attenuation

<u>**Shadow curves**</u>

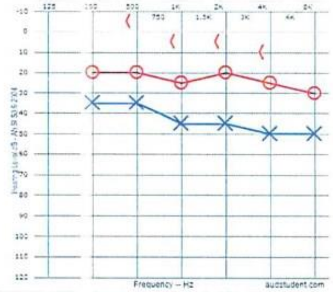
Shadow curves happen when the sound to the bad ear is loud enough to overcome interaural attenuation and be heard by the good ear (the non-test ear).

Shadow curves show cross-hearing! Not every situation with cross-hearing will have a shadow curve, but some do – so they're important to recognise.

Example 1: right ear has normal hearing and left ear is totally dead



Example 2: right ear has a conductive hearing loss (gaps between AC and BC thresholds) and left ear is totally dead



	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	⌶ or □	>	]

The left ear is showing a shadow curve, mimicking the shape of the right ear bone conduction (BC) hearing thresholds.

The shadow curves for both examples are **exactly the same,** despite a difference in the right ear's air conduction (AC) thresholds.

Unmasked thresholds seen in shadow curves will likely need masking!

Interaural attenuation is a bone conduction mechanism: the difference in dB between the ears is mostly lost *through* the head, not around it (via the air).

Q) Do shadow curves mimic the **bone** conduction thresholds or **air** conduction thresholds of the better ear? ___________

5. **Bone conduction testing**

Cross-hearing and interaural attenuation
Case 01.

ⓘ IA for the bone conduction vibrator is 0dB – but you **don't** need to change the IA figure in maskME

a) Test the **left** ear BC threshold at 1000Hz. At what level is there a response? ___________

b) What ear is responding at that level? Right/left

c) What is the true **left** ear's BC threshold at 1000Hz? (look at the black line!) ___________

d) Test the **right** ear bone conduction at 1000Hz. At what level is there a response?

____

e) What is the difference between the left and right unmasked bone conduction thresholds?
((a) and (d)) _____________

ⓘ IA for the bone-conduction vibrator is 0dB! This means that you can present 50dB signal to the right ear and the left ear will also detect a 50dB signal.

Part 2: doing masking

When cross-hearing happens (the non-test ear (NTE) responds before the test ear (TE)), masking is needed to find out the TE's actual threshold. Cross-hearing can happen in both air-conduction and bone-conduction testing. So, we can mask AC or BC thresholds.

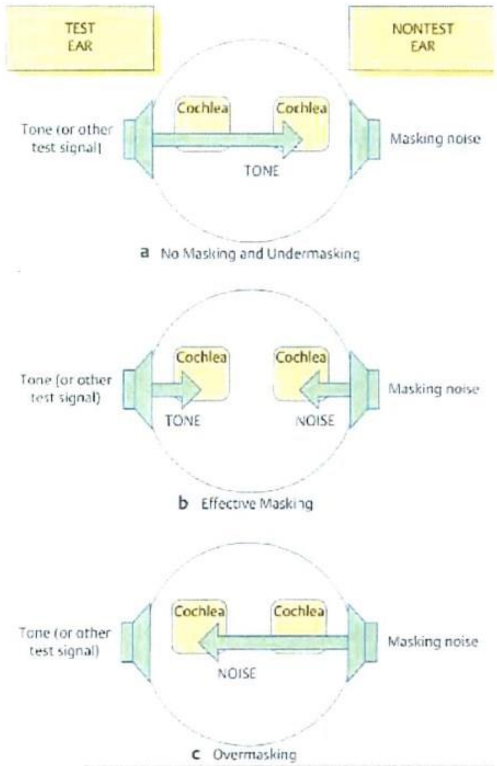
Masking noise is a type of white noise that helps to separate the ears by 'keeping the NTE busy' so that it can't respond to the test signal. It 'keeps it busy' by worsening the NTE's threshold so that it is unable to hear the test signal.

Masking noise is always presented to the NTE using a headphone or insert earphone, never the bone conductor.

Masking noise is increased in 10dB steps while responses to the test signal are checked. This technique is called Hood's plateau method of masking.

When there are responses despite increases in masking noise, the response is coming from the TE cochlea. This is the *plateau.*

3 stages of masking and the plateau curve



Undermasking

Reponses are from the non-test ear

Not enough masking noise to worsen the non-test ear threshold

Plateau (*effective masking*)

Reponses are from the test ear at true threshold

Masking sound is sufficiently strong to worsen the non-test ear threshold, and eliminate its ability to respond to signals to the test ear

Overmasking

Responses are from test ear but not at true threshold – at a worse threshold

Masking sound is intense enough to be audible in the test ear, worsening the test ear's ability to detect the test signal

The plateau curve

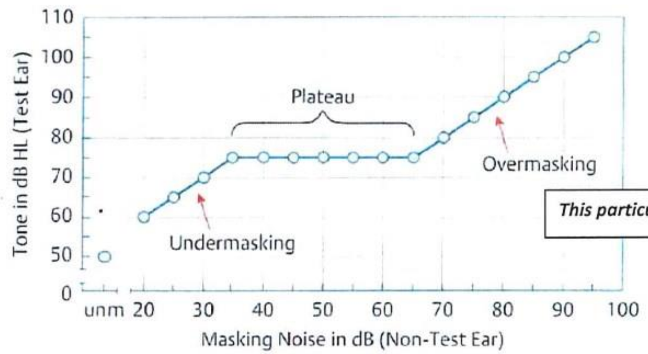


Image from Gelfand 2015 p.260

This particular plateau is 30dB wide

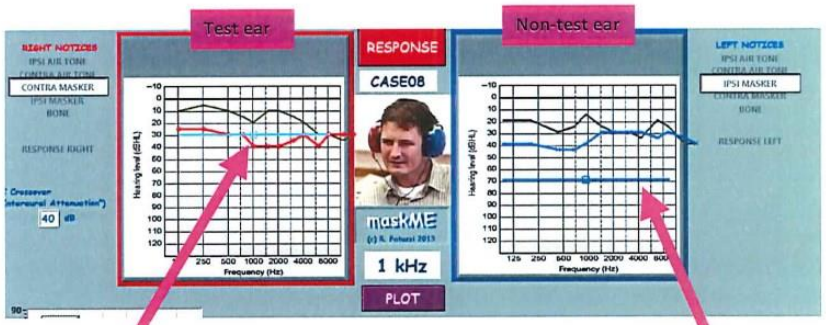
Overmasking

The louder the masking noise is, the sooner overmasking can happen.

Overmasking shortens the plateau width.

If overmasking happens before you can even get a 15dB plateau, you cannot mask that threshold. This is a **masking dilemma**, and it is impossible to know the true threshold.

Overmasking in maskME – what it looks like



Light blue line = level of masking noise in test ear

Because the light blue line is below (more intense than) the bone conduction threshold of the test ear, overmasking is happening

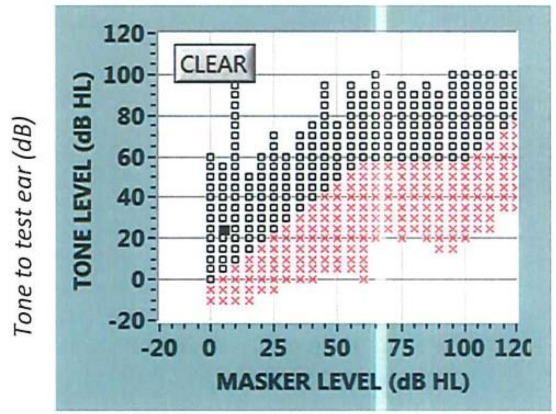
Dark blue line = masker is in non-test ear at 70dB

The plateau in maskME

Class demonstration – Case 01, testing the left ear bone conduction threshold at 2000Hz

☐ indicates a response – but could be from either ear

X indicates *no* response from either ear



This plateau is 40dB wide before overmasking starts

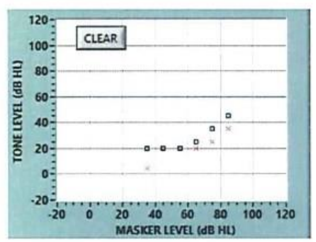
Masking sound to non-test ear – the better ear (dB)

The plateau curve shows us that the test ear's true threshold is at 60dB.

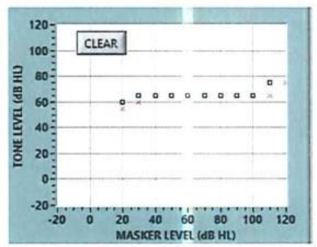
In some cases, such as for conductive hearing losses (with air-bone gaps of 15dB or more), a short plateau of 15dB can be accepted. Always try to get a plateau!

A plateau of 5dB or 10dB is **not enough** – responses to the test tone cannot be accepted as coming from the TE until there is a plateau of at least 15dB, usually 20dB.

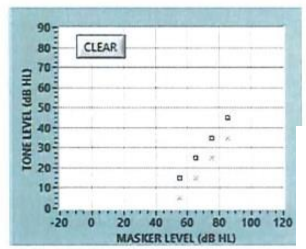
Examples of different plateau widths in maskME



30dB plateau width



70dB plateau width



No plateau! Sometimes it is impossible to get a plateau of even 15dB

6. Air conduction masking and the plateau

Case 14

Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's air conduction (AC) threshold at 2000Hz. What level (dB) is there a response, from either ear? ________________

b) What is the **right** ear's bone conduction (BC) threshold at 2000Hz? ____________

c) What is the difference between (a) and (b)? ____________

d) How does this figure compare to the interaural attenuation? ______________________

Go back to testing the left ear AC and find its threshold again– turn off the bone conduction slider!

e) Now turn on the **right** air masking button. How loud do you have to make the masking noise to stop the cross-hearing response? ________________

Use the plateau plotter in maskME for the following activity PLOT

f) Increase the level of the **left** AC tone until there is a response and use the Plot button to plot the response.

Every time the **left** ear (the test ear) responds, increase the masking noise in the **right** ear by 10dB. Plot each point.

Every time the **right** ear (the non-test ear) responds, increase the AC tone by 5dB. Plot each point.

Continue to plot responses **and** non-responses until you have been able to obtain a 20dB plateau (i.e. an increase of 20dB in masking noise with no change in threshold in the left ear)

This masking procedure is called the Hood Procedure.

g) What is the **left** ear's true (i.e. masked) AC threshold at 2000Hz? ____________

h) Continue to increase the masking noise and tone level and plot the results. What happens after the plateau?

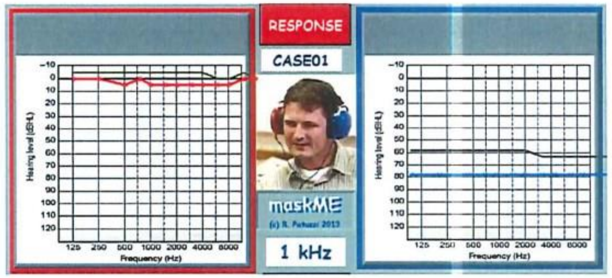
____

____

Overmasking occurs when the masking noise is audible in the test ear cochlea, raising its threshold, and interfering with its ability to respond at its true threshold.

7. Air conduction masking and the plateau

Case 01



Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's air conduction (AC) threshold at 1000Hz. What level (dB) is there a response, from either ear? ______________

b) Turn on masking in the **right** ear at 25dB.

c) Plot responses and non-responses on the plateau plotter.

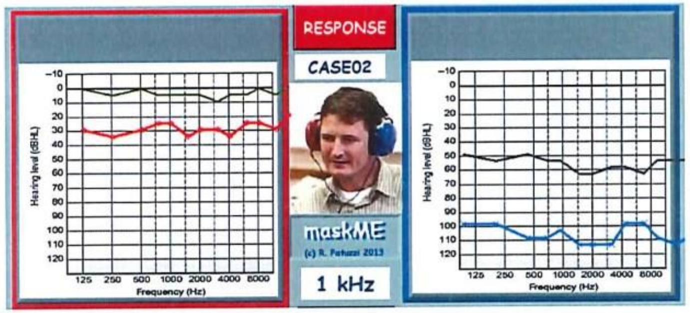
*Every time the **left** ear (the test ear) responds, increase the masking noise in the **right** ear by 10dB. Plot each point.*

*Every time the **right** ear (the non-test ear) responds, increase the AC tone by 5dB. Plot each point.*

d) What is the **left** ear's true (i.e. masked) AC threshold at 1000Hz? ____________

8. Air conduction masking and the plateau

Case 02



Use supra-aural headphones– IA is 40dB

a) Test the left ear's air conduction (AC) threshold at 1000Hz. What level (dB) is there a response, from either ear? ______________

b) Turn on masking in the right ear at 45dB.

c) Plot responses and non-responses on the plateau plotter.

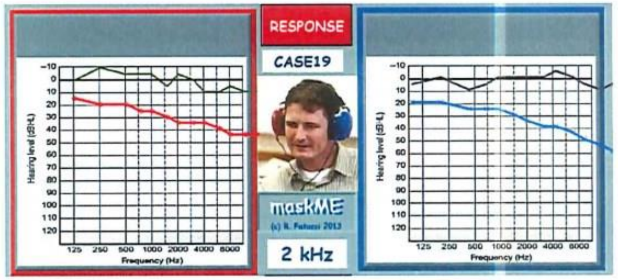
Every time the left ear (the test ear) responds, increase the masking noise in the right ear by 10dB. Plot each point.

Every time the right ear (the non-test ear) responds, increase the AC tone by 5dB. Plot each point.

d) What is the left ear's true (i.e. masked) AC threshold at 1000Hz? ____________

9. Masking bone conduction and differences in interaural attenuation

Case 19



Use the plateau plotter in maskME for the following activities

*** Ensure IA is set to 40dB for supra-aural headphones.**

Test the left ear BC threshold at 1000Hz.

Start the masking noise at 45dB in the right ear and plot the plateau curve until you reach 120dB of masking noise.

a) How wide is the plateau? __________

b) At what masking level does overmasking start? __________

A plateau must be at least 15dB wide to be considered a plateau! If it is less than 15dB, we cannot trust that the responses are from the test ear.

*** Change IA to 60dB for insert-earphones**

Test the left ear BC threshold at 1000Hz

Start masking at 45dB and plot the plateau curve until you reach 120dB of masking.

c) How wide is the plateau? __________

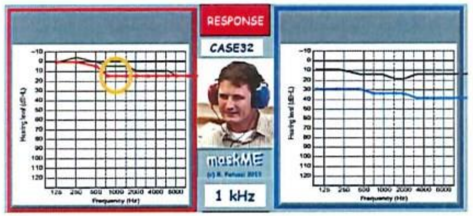
d) At what masking level does overmasking start? __________

e) Circle one
Larger interaural attenuation values result **in longer/shorter/no different** plateau widths.

Extra cases for fast workers!

Masking bone conduction and air-bone gaps

10. Case 32



Use supra-aural headphones– IA is 40dB

a) How large is the conductive component (difference between AC and BC thresholds, i.e. the air-bone gap) in the **right** ear at 500Hz? ________________

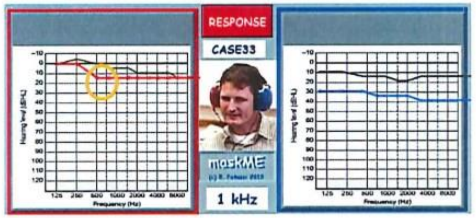
Find the unmasked **left** BC threshold at 500Hz. The unmasked threshold is the quietest level at which there is a response *from either ear*.

Start masking at 30dB in the **right** ear and plot the plateau curve.

Plot two points of overmasking

b) How wide (in dB) is the plateau before overmasking starts? ____________

11. Case 33



a) How large is the conductive component (difference between AC and BC threshold in the **right** ear at 500Hz? ________________

Find the unmasked **left** BC threshold at 500Hz and then start masking at 45dB in the **non-test ear** and plot the plateau curve.

More masking noise is required (than for Case 32) because the noise will be attenuated by the amount of the conductive component, but it still must reach the non-test ear cochlea at the same level as in Case 32.

Plot two points of overmasking

b) How wide (in dB) is the plateau before overmasking starts? ___________

c) Circle one
Larger conductive components result **in longer/shorter/no different** plateau widths.

Case 33 (Question 11) shows a **masking dilemma,** where it is not possible to even get a 15dB plateau (the minimum width acceptable). This occurs when the minimum amount of masking needed in the non-test ear is strong enough to be audible in the test ear, resulting in overmasking happening almost immediately.

12. Air conduction masking
Case 06

Use supra-aural headphones– IA is 40dB

Use the plateau plotter in maskME for the following activity

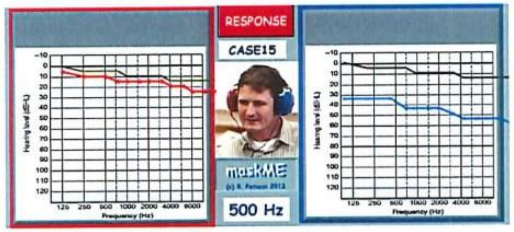
1. Test the **right** ear AC threshold at 2000Hz and leave the AC slider at threshold, i.e. the quietest level of response *from either ear.*
2. Start masking noise in the **left** ear at 65dB
3. Plot at least 8 points of responses and non-responses
4. Are you able to get a plateau? If so, how wide is it?

____

____

Extra cases for fast workers!

13.. Masking bone conduction
Case 15



Use supra-aural headphones– IA is 40dB

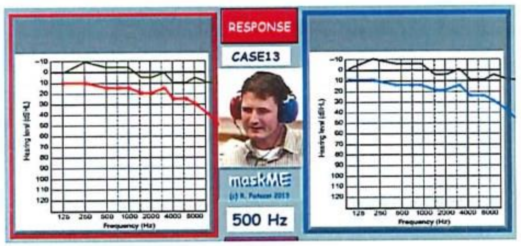
Use the plateau plotter in maskME for this activity

Test the **left** ear **bone** conduction at 500Hz.

Start the masking noise level in the **right** ear at 40dB.

a) Were you able to get a plateau? If so, how wide was it? ____________________

1. **Masking bone conduction**
   Case 13



Use supra-aural headphones– IA is 40dB

Use the plateau plotter in maskME for this activity

Test the **right** ear **bone** conduction at 4000Hz.

Start masking at 35dB in the **left** ear.

a) Were you able to get a plateau? If so, how wide was it? ____________________

Compare your answers with your neighbour

The occlusion effect

What is it?

An increase in low-frequency sounds when an ear/the ears are blocked.

Like when you block your ears and talk and notice that your voice sounds deeper.

When does it happen in hearing testing?

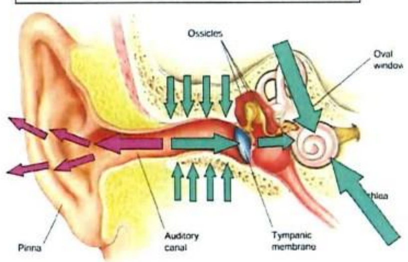
1. When we need to mask the non-test ear during bone conduction – one ear is blocked
2. When we measure air-conduction thresholds – both ears are blocked.

Why does it happen?

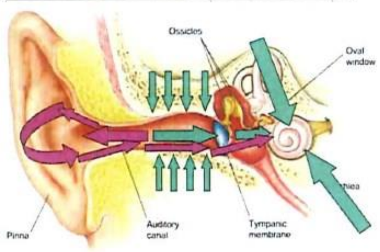
When the ears are unoccluded, some low-frequency sound - 1000Hz and under - is able to leak *out* of the ear canals and into the environment.

This leakage happens in the first stage of bone conduction testing when both ears are unoccluded.

Unoccluded – pink arrows show low frequency sounds escaping out of the ear canal



Occluded – pink arrows show low frequency sounds reflecting back into the cochlea



Bone-conducted test signals vibrate the whole skull. When there is something blocking the non-test ear (like a masking headphone), the sound that normally leaks out is reflected back down the ear canal and into the non-test ear cochlea.

Occluding the ear traps that low frequency sound in, adding to the sound in the cochlea.

This results in more sound reaching the non-test ear cochlea, which means the sound is louder! This gives *better* BC thresholds at the non-test ear cochlea.

NB: Improved BC thresholds due to the occlusion effect are not reflective of better cochlear sensitivity: an ear doesn't start hearing better because it is occluded – it appears to be hearing 'better' simply because there is *more* sound at the cochlea.

Is it a problem?

1. Yes, it is a problem in masked bone conduction testing for 500Hz and 1000Hz. Occluding the non-test ear increases the intensity of a bone-conducted signal in the non-test ear, making it more likely to respond to the test tone than the test ear (by cross-hearing).

2. The occlusion effect is *not* a problem in air conduction testing, even though both ears are occluded with the headphones or insert earphones. In air-conduction testing, there is no comparison between unoccluded and occluded thresholds, and the occlusion effect for air-conduction testing is calibrated into the testing equipment.

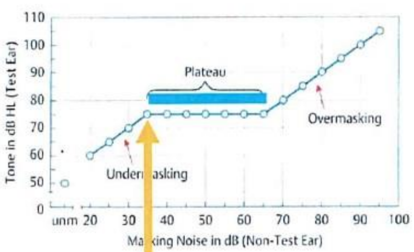
3. The OE is *not* a problem during unoccluded bone conduction testing as nothing occludes the ears.

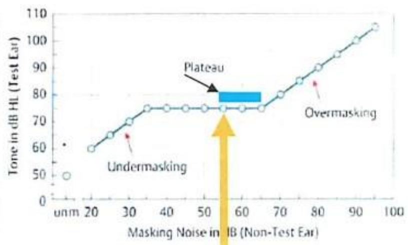
Bone conduction masking and the occlusion effect

The occlusion effect is a problem during masked BC testing because more masking noise (10-20dB) is needed to cover the increase of sound energy in the non-test ear cochlea.

More masking noise is needed to offset the occlusion effect. The starting level masking noise in the non-test ear needs to 'reset' the improvement in BC threshold back to the original unoccluded threshold.

More masking noise always results in reaching the point of overmasking earlier, and therefore results in a shorter plateau width. It may impact the tester's ability to even get a 15dB plateau.





Yellow arrow shows level at which masking starts. Blue line shows width of plateau

Example 1: no extra masking added to compensate for the occlusion effect. Masking noise starts at 35dB. Overmasking starts after 65dB of masking.

Example 2: an extra 20dB of masking is added to compensate for the occlusion effect – masking starts at 55dB. Overmasking starts after 65dB of masking – impossible to get even a 15dB plateau.

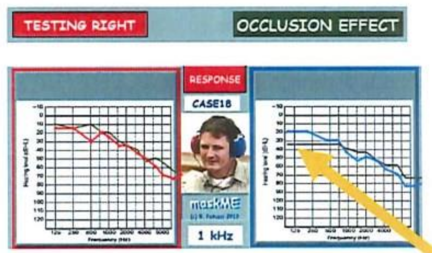
How large is the occlusion effect?

The OE must be added on to the initial masking level in order to effectively mask the non-test ear and eliminate its participation in hearing the test tones to the test ear. In clinical masking, large, 'worst-case scenario' average values are used, which are added onto the initial masking level.

The average size of the occlusion effect varies from 10-20dB depending on whether headphones or insert earphones were used, and on the frequency of the test tone.

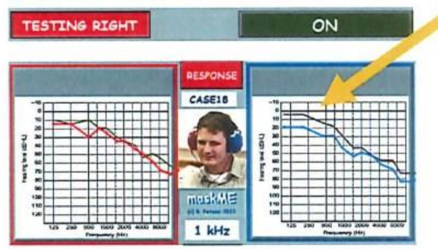
maskME shows you how the occlusion effect looks:

Occlusion effect **off**



Notice the difference in bone conduction thresholds in the non-test ear (left) at 1000Hz and under.

Occlusion effect **on**



Because the BC thresholds have improved in the non-test ear, cross-over happens at a lower level than without the occlusion effect on.

Q) The occlusion effect for supra-aural headphones at 500Hz is 20dB. If a 500Hz pure-tone is presented to the test ear at 35dB, what level is it *actually* present at in the non-test ear cochlea? ____________

15. **Masking BC and the occlusion effect**
Case 08

ⓘ Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's BC threshold at 1000Hz. At what level is there a response? ___________

b) Which ear is responding to this with the OE button off? ___________

c) Which ear is responding to this with the OE button on? ___________

d) If the non-test ear is occluded, what does this mean for the likelihood of cross-hearing in that ear?

____

____

e) What would this mean for the likelihood of overmasking?

____

____

c) Circle one
Larger occlusion effects result **in longer/shorter/no different** plateau widths.

Masking – takeaway points

The **purpose** of masking is to get accurate ear-specific information. Masking is the process of presenting a 'white' noise into the non-test ear and varying the level until responses are reliably only coming from the test ear.

Interaural attenuation is the reduction in the amount of skull vibration as sound travels from one cochlea to the other, through the skull via bone conduction mechanisms. IA varies depending on transducer type and type of sound (e.g. pure tone, masking noise, or speech stimuli).

Crossover is the portion of the signal from the test ear that physically reaches the non-test ear (NTE) via interaural attenuation. It may or may not be heard, depending on how well the NTE can hear.

Cross-hearing is when the level at which the sound crosses over is *audible* in the NTE. The NTE cochlea must be sensitive enough to detect the crossed-over sound to be able to respond to it. When cross-hearing is suspected, masked thresholds must be sought.

Air conduction thresholds are masked on a frequency-by-frequency basis when cross-hearing is suspected. It is important to look at the difference in dB between the ears at each frequency, looking for differences of IA or greater. It is particularly important to look at the bone conduction threshold of the better ear and compare it to the air conduction threshold of the worse ear. Compare between air conduction thresholds at each frequency as well as the AC of one ear and BC of the other.

Bone conduction thresholds are masked based on the presence of an air-bone gap of 15dB or more. Masked thresholds will determine whether the ABG represents a true conductive component in the test ear, or if the unmasked bone conduction threshold is coming from the other ear.

A masking **plateau** is reached when increases in masker level do not affect the test ear's ability to respond to the signal at a particular level. This level can be accepted as the test ear's masked threshold once an increase of 20dB in masker noise does not affect the responses. In some situations (e.g. bilateral conductive hearing loss), a plateau of 15dB can be accepted.

The **occlusion effect** occurs when an ear is occluded (e.g. with a headphone on the NTE for masking) and traps more sound in the ear canal. This leads to greater sound energy at the cochlea, which is perceived as a louder sound. This results in BC results appearing better than they are. It must be countered by adding more masking noise to the NTE, which then increases the risk of overmasking

Overmasking happens when the masking sound is strong enough to cross through the head and be heard by the test ear! It can make the test ear's thresholds appear worse than they actually are. Overmasking is most likely to happen in cases of conductive hearing loss.

Masking dilemmas occur when the amount of masking noise needed to effectively elevate the NTE's threshold is strong enough to cross the head and be audible in the test ear, resulting in an overmasking situation. They are most common with bilateral conductive losses, or one ear with a conductive loss and one ear with a sensorineural loss. It can be impossible to get masked thresholds in these situations.

Always ask yourself: is there any chance that the non-test ear can hear the sound presented to the test ear?

WORKBOOK D – AUDIOLOGY STUDENTS

Clinical masking workbook

E

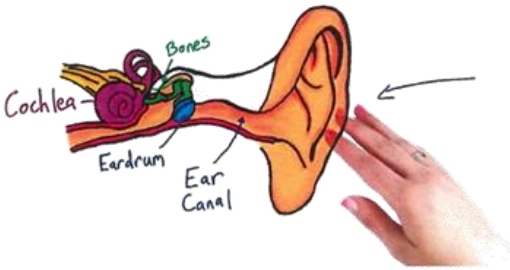
Part 1: Interaural attenuation and cross-hearing

Part 2: Doing masking

Intended learning outcomes

1. Understand interaural attenuation
2. Understand cross-hearing
3. Understand shadow curves
4. Understand the purpose of masking
5. Understand the plateau
6. Understand overmasking
7. Understand how the following affect plateau width
   -interaural attenuation
   -the occlusion effect
   -the size of conductive components

Recap learning outcomes on page 22!



Part 1. Interaural attenuation and cross-hearing

The two cochleas are connected by structures in the head. If a sound is intense enough in one ear, it can also be audible in the other ear.

When you're testing one ear, and the *other* ear responds first, ***cross-hearing*** is happening! This is problematic for testing.

Interaural attenuation **(IA) is how much a sound is attenuated as it travels from one ear to the other through the skull.** It depends on test stimuli (e.g. frequency) and transducer (speaker). For example, the bone conduction vibrator has an IA of 0dB, and IA for air-conduction transducers (supra-aural headphones and insert earphones) varies from 40-75dB.

A small IA (e.g. 0dB) means that 0dB of energy is lost between the cochleas; i.e. when one ear is given a 20dB pure tone sound, 20dB also arrives to the other cochlea.

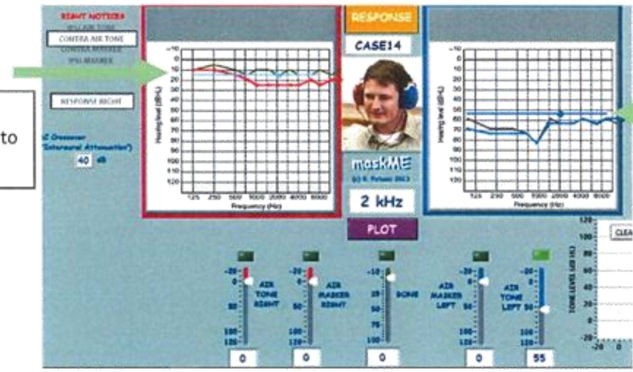
A large IA (e.g. 60dB) means that if one ear is presented with a 70dB pure tone sound, 60dB of it is lost in transmission between the cochleas, and only 10dB of it arrives at the other cochlea after passing through the skull.

Example

1) Find the left ear's air conduction threshold at 2000Hz. Use the Air Tone slider to find this out.

Use supra-aural headphones– IA is 40dB

Light blue line = level of crossover to non-test ear



Horizontal blue line = level of signal to test ear

Crossover is the portion of the signal from the test ear that physically reaches the non-test ear cochlea via interaural attenuation. It may or may not be heard, depending on how well the non-test ear can hear.

Cross-hearing is when the level at which the sound crosses over is *audible* in the non-test ear. The non-test ear cochlea must be sensitive enough to detect the crossed-over sound to be able to respond to it.

Cross-hearing is what we need to consider when doing hearing testing!

1. **Cross-hearing and interaural attenuation**
   Case 36 in maskME. Right ear normal and dead left ear

No thresholds in the audiogram = no responses at all (i.e. dead ear!)

Ask yourself: is there an obvious better ear? If one ear is much better than the other, it is possible that cross-hearing may occur.

a) Test the **right** ear air conduction threshold (using the Air Tone slider) at 4000Hz. What is the lowest level (in dB) at which there is a response from either ear?

____

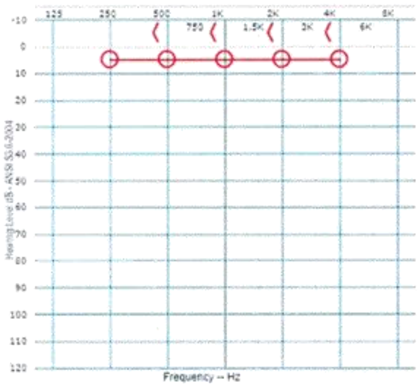
b) Which ear is responding? Right/left

c) Test the **left** ear air conduction threshold at 4000Hz. At what level is there a response (from either ear)? ____________
Plot that on the audiogram below using a cross symbol.

d) Which ear responds at this level? Right/left

If the non-test ear responds before the test ear, masking will be required to get separate ear information

e) Complete the **left** ear air conduction results for 500, 1000 and 2000Hz on the audiogram below. Use cross symbols.



Compare your answers with your neighbour

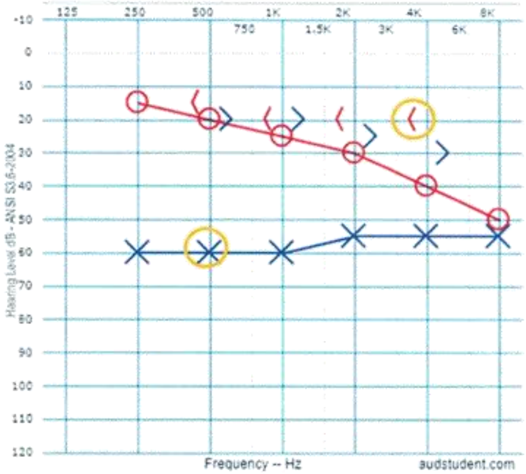
	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	I or □	>	]

This is called the *shadow curve*: the unmasked left ear thresholds shadow the right ear BC thresholds.

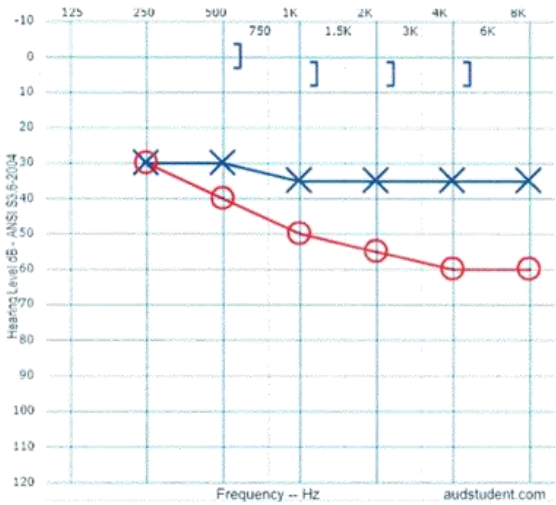
Compare your answers with your neighbour

Cross-hearing and interaural attenuation
Spotting cross-hearing

2. Circle any threshold that should be masked if you got these results using supra-aural headphones (interaural attenuation: 40dB) and the bone conduction vibrator (interaural attenuation: 0dB). The first two have been done for you.



3. Circle any threshold that should be masked if you got these results using supra-aural headphones (interaural attenuation: 40dB for all frequencies) and the bone conduction vibrator (interaural attenuation: 0dB)



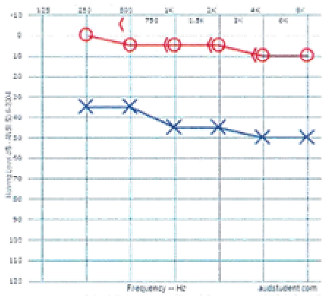
Cross-hearing and interaural attenuation

Shadow curves

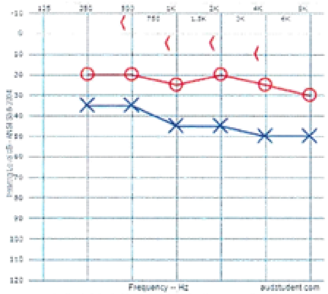
Shadow curves happen when the sound to the bad ear is loud enough to overcome interaural attenuation and be heard by the good ear (the non-test ear).

Shadow curves show cross-hearing! Not every situation with cross-hearing will have a shadow curve, but some do – so they're important to recognise.

Example 1: right ear has normal hearing and left ear is totally dead



Example 2: right ear has a conductive hearing loss (gaps between AC and BC thresholds) and left ear is totally dead



	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	X or □	>	]

The left ear is showing a shadow curve, mimicking the shape of the right ear bone conduction (BC) hearing thresholds.

The shadow curves for both examples are **exactly the same**, despite a difference in the right ear's air conduction (AC) thresholds.

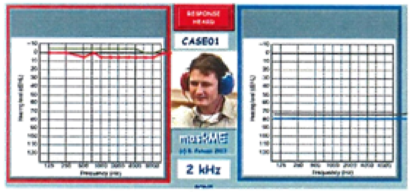
Unmasked thresholds seen in shadow curves will likely need masking!

Interaural attenuation is a bone conduction mechanism: the difference in dB between the ears is mostly lost *through* the head, not around it (via the air).

Q) Do shadow curves mimic the **bone** conduction thresholds or **air** conduction thresholds of the better ear? ___________

4. **Bone conduction testing**

Cross-hearing and interaural attenuation
Case 01.



IA for the bone conduction vibrator is 0dB – but you **don't** need to change the IA figure in maskME

a) Test the **left** ear BC threshold at 1000Hz. At what level is there a response? ___________

b) What ear is responding at that level? Right/left

c) What is the true **left** ear's BC threshold at 1000Hz? (look at the black line!) ___________

d) Test the **right** ear bone conduction at 1000Hz. At what level is there a response? ___________

e) What is the difference between the left and right unmasked bone conduction thresholds? ((a) and (d)) ___________

IA for the bone-conduction vibrator is 0dB! This means that you can present 50dB signal to the right ear and the left ear will also detect a 50dB signal.

Part 2: doing masking

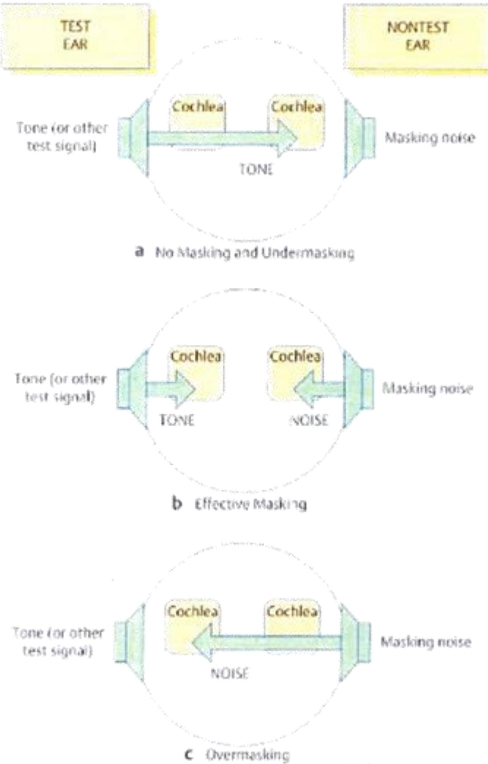
When cross-hearing happens (the non-test ear (NTE) responds before the test ear (TE)), masking is needed to find out the TE's actual threshold. Cross-hearing can happen in both air-conduction and bone-conduction testing. So, we can mask AC or BC thresholds.

Masking noise is a type of white noise that helps to separate the ears by 'keeping the non-test ear busy' so that it can't respond to the test signal. It 'keeps it busy' by worsening the NTE's threshold so that it is unable to hear the test signal.

Masking noise is always presented to the NTE using a headphone or insert earphone, never the bone conductor.

Masking noise is increased in 10dB steps while responses to the test signal are checked. This technique is called Hood's plateau method of masking.

When there are responses despite increases in masking noise, the response is coming from the TE cochlea. This is the *plateau*.



3 stages of masking and the plateau curve

Undermasking

Reponses are from the non-test ear

Not enough masking noise to worsen the non-test ear threshold

Plateau (*effective masking*)

Reponses are from the test ear at true threshold

Masking sound is sufficiently strong to worsen the non-test ear threshold, and eliminate its ability to respond to signals to the test ear

Overmasking

Responses are from test ear but not at true threshold – at a worse threshold

Masking sound is intense enough to be audible in the test ear, worsening the test ear's ability to detect the test signal

7

The plateau curve

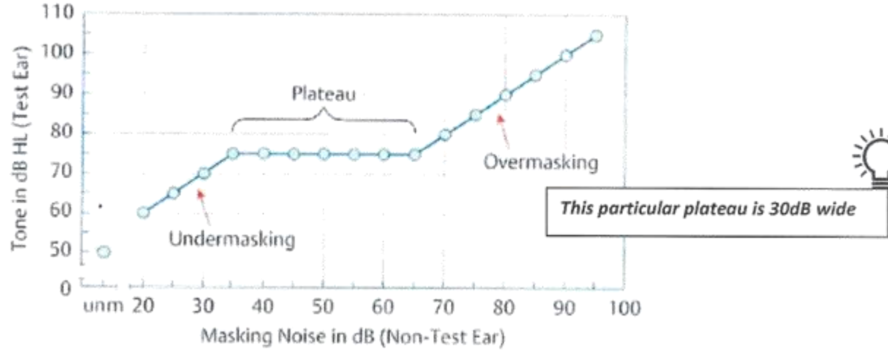


Image from Gelfond 2015 p.260

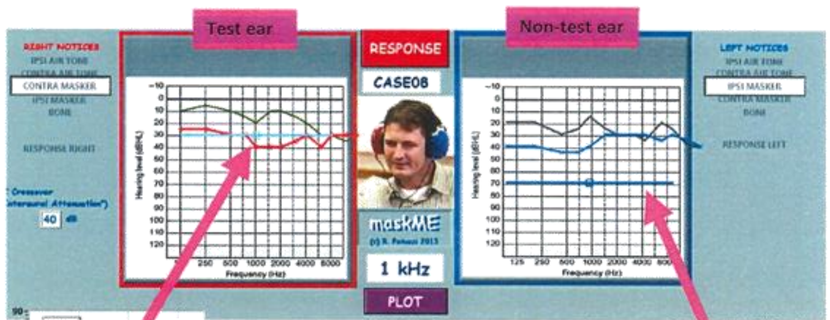
Overmasking

The louder the masking noise is, the sooner overmasking can happen.

Overmasking shortens the plateau width.

If overmasking happens before you can even get a 15dB plateau, you cannot mask that threshold. This is a **masking dilemma**, and it is impossible to know the true threshold.

Overmasking in maskME – what it looks like



Light blue line = level of masking noise in test ear

Because the light blue line is below (more intense than) the bone conduction threshold of the test ear, overmasking is happening

Dark blue line = mask in non-test ear at 70d

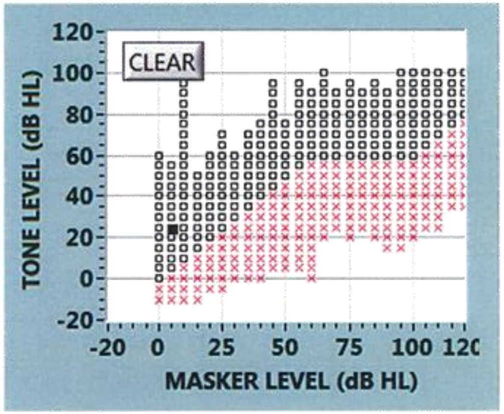
8

The plateau in maskME

Class demonstration – Case 01, testing the left ear bone conduction threshold at 2000Hz

☐ indicates a response – but could be from either ear

X indicates *no* response from either ear



Tone to test ear (dB)

This plateau is 40dB wide before overmasking starts

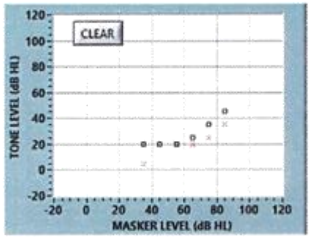
Masking sound to non-test ear – the better ear (dB)

The plateau curve shows us that the test ear's true threshold is at 60dB.

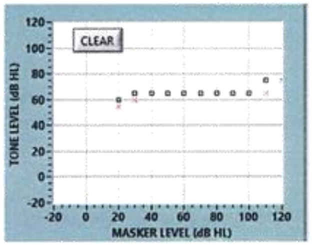
In some cases, such as for conductive hearing losses (with air-bone gaps of 15dB or more), a short plateau of 15dB can be accepted. Always try to get a plateau!

A plateau of 5dB or 10dB is **not enough** – responses to the test tone cannot be accepted as coming from the test ear until there is a plateau of at least 15dB, usually 20dB.

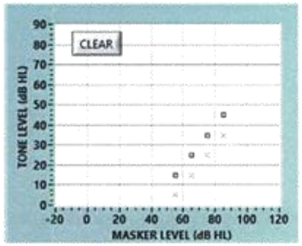
Examples of different plateau widths in maskME



30dB plateau width



70dB plateau width

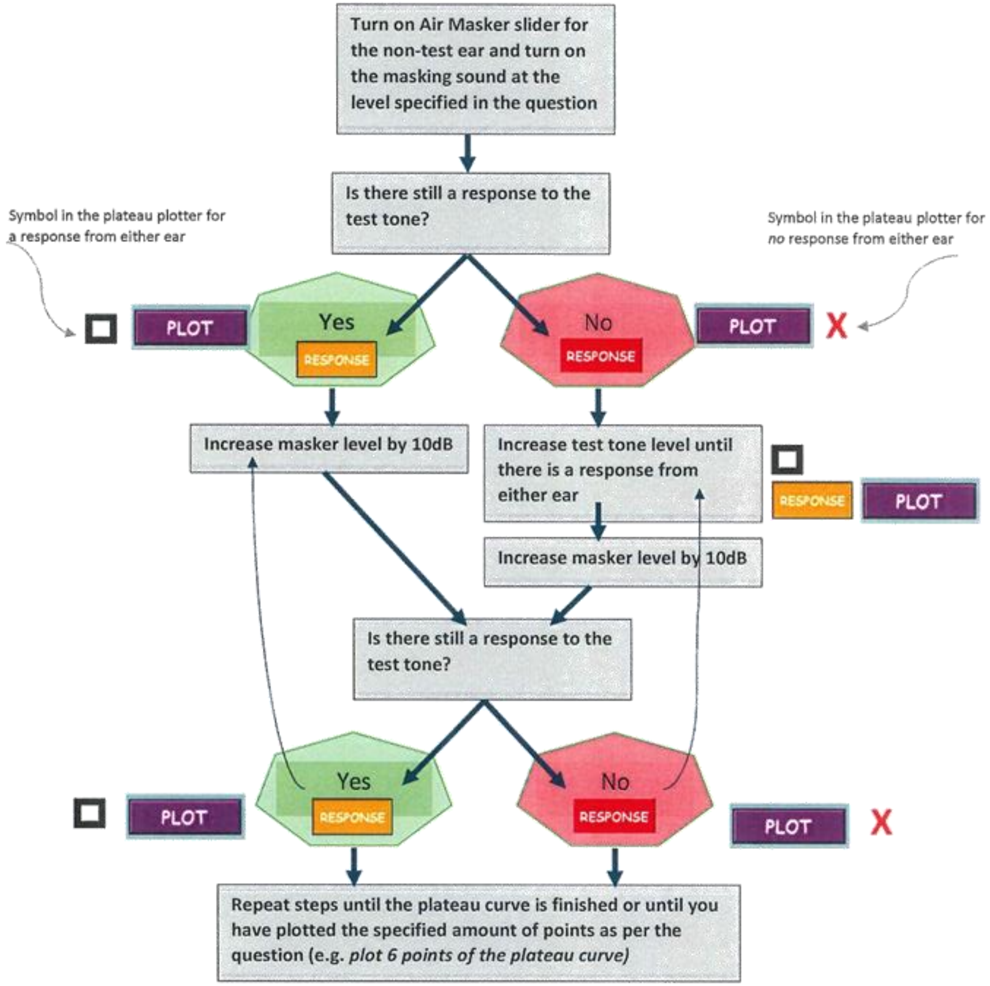


No plateau! Sometimes it is impossible to get a plateau of even 15dB

The Hood masking procedure!

The procedure is done when cross-hearing is occurring: when the non-test ear hears the test tone before the test ear.

The goal is to find a plateau of at least 20dB to establish the true threshold of the test ear.



If you cannot get a 20dB plateau to establish threshold (i.e. 2 increases of 10dB in masking noise, try to get a 15dB plateau to establish threshold

Every time there is a response or *non-response*, use the Plot button to plot the plateau curve! PLOT

6. Air conduction masking and the plateau

Case 14

Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's air conduction (AC) threshold at 2000Hz. What level (dB) is there a response, from either ear? ____________

b) What is the **right** ear's bone conduction (BC) threshold at 2000Hz? ________

c) What is the difference between (a) and (b)? ________

d) How does this figure compare to the interaural attenuation? ______________

Go back to testing the left ear AC and find its threshold again– turn off the bone conduction slider!

e) Now turn on the **right** air masking button. How loud do you have to make the masking noise to stop the cross-hearing response? __________

Use the plateau plotter in maskME for the following activity PLOT

f) Increase the level of the **left** AC tone until there is a response and use the Plot button to plot the response.

Every time the **left** ear (the test ear) responds, increase the masking noise in the **right** ear by 10dB. Plot each point.

Every time the **right** ear (the non-test ear) responds, increase the AC tone until there is a response. Plot each point.

Continue to plot responses **and** non-responses until you have been able to obtain a 20dB plateau (i.e. an increase of 20dB in masking noise with no change in threshold in the left ear)

This masking procedure is called the Hood Procedure.

g) What is the **left** ear's true (i.e. masked) AC threshold at 2000Hz? ________

h) Continue to increase the masking noise and tone level and plot the results. What happens after the plateau?

____

Overmasking occurs when the masking noise is audible in the test ear cochlea, raising its threshold, and interfering with its ability to respond at its true threshold.

7. Air conduction masking and the plateau

Case 01

Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's air conduction (AC) threshold at 1000Hz. What level (dB) is there a response, from either ear? ________

b) Turn on masking in the **right** ear at 25dB.

c) Plot responses and non-responses on the plateau plotter.

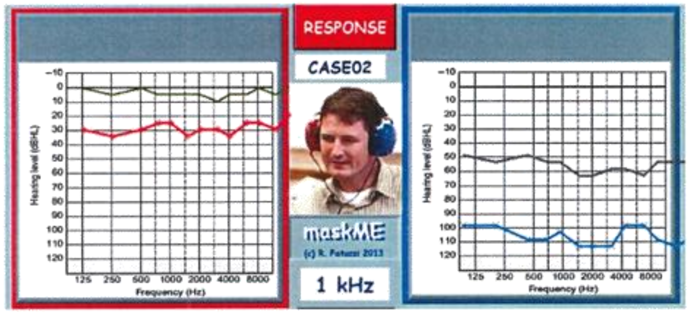
*Every time the **left** ear (the test ear) responds, increase the masking noise in the **right** ear by 10dB. Plot each point.*

*Every time the **right** ear (the non-test ear) responds, increase the AC tone until there is a response. Plot each point.*

d) What is the **left** ear's true (i.e. masked) AC threshold at 1000Hz? ________

8. Air conduction masking and the plateau

Case 02



Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's air conduction (AC) threshold at 1000Hz. What level (dB) is there a response, from either ear? ______________

b) Turn on masking in the **right** ear at 45dB.

c) Plot responses and non-responses on the plateau plotter.

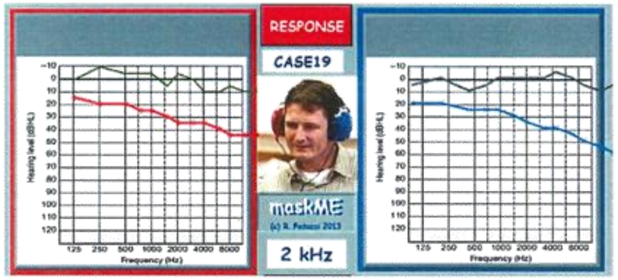
*Every time the **left** ear (the test ear) responds, increase the masking noise in the **right** ear by 10dB. Plot each point.*

*Every time the **right** ear (the non-test ear) responds, increase the AC tone until there is a response. Plot each point.*

d) What is the **left** ear's true (i.e. masked) AC threshold at 1000Hz? ____________

9. Masking bone conduction and differences in interaural attenuation

Case 19



Use the plateau plotter in maskME for the following activities

*** Ensure IA is set to 40dB for supra-aural headphones.**

Test the **left** ear BC threshold at 1000Hz.

Start the masking noise at 45dB in the **right** ear and plot the plateau curve until you reach 120dB of masking noise.

a) How wide is the plateau? __________

b) At what masking level does overmasking start? __________

A plateau must be at least 15dB wide to be considered a plateau! If it is less than 15dB, we cannot trust that the responses are from the test ear.

*** Change IA to 60dB for insert-earphones**

Test the **left** ear BC threshold at 1000Hz

Start masking at 45dB and plot the plateau curve until you reach 120dB of masking.

c) How wide is the plateau? __________

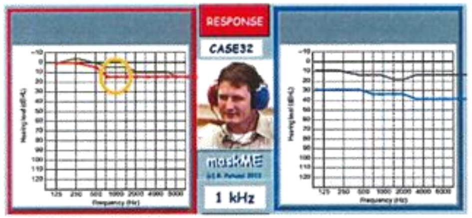
d) At what masking level does overmasking start? __________

e) Circle one
Larger interaural attenuation values result **in longer/shorter/no different** plateau widths.

Extra cases for fast workers!

Masking bone conduction and air-bone gaps

10. Case 32



Use supra-aural headphones– IA is 40dB

a) How large is the conductive component (difference between AC and BC thresholds, i.e. the air-bone gap) in the **right** ear at 500Hz? ________________

Find the unmasked **left** BC threshold at 500Hz. The unmasked threshold is the quietest level at which there is a response *from either ear*.

Start masking at 30dB in the **right** ear and plot the plateau curve.

Plot two points of overmasking

b) How wide (in dB) is the plateau before overmasking starts? ____________

11. Case 33

a) How large is the conductive component (difference between AC and BC threshold in the **right** ear at 500Hz? ________________

Find the unmasked **left** BC threshold at 500Hz and then start masking at 45dB in the **non-test ear** and plot the plateau curve.

More masking noise is required (than for Case 32) because the noise will be attenuated by the amount of the conductive component, but it still must reach the non-test ear cochlea at the same level as in Case 32.

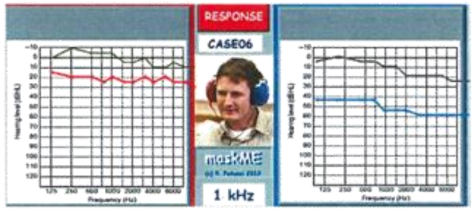
Plot two points of overmasking

b) How wide (in dB) is the plateau before overmasking starts? ___________

c) Circle one
Larger conductive components result **in longer/shorter/no different** plateau widths.

Case 33 (Question 11) shows a **masking dilemma,** where it is not possible to even get a 15dB plateau (the minimum width acceptable). This occurs when the minimum amount of masking needed in the non-test ear is strong enough to be audible in the test ear, resulting in overmasking happening almost immediately.

12. Air conduction masking
Case 06



Use supra-aural headphones– IA is 40dB

Use the plateau plotter in maskME for the following activity

Test the **right** ear AC threshold at 2000Hz and leave the AC slider at threshold, i.e. the quietest level of response *from either ear*.

Start masking noise in the **left** ear at 65dB

Plot at least 8 points of responses and non-responses

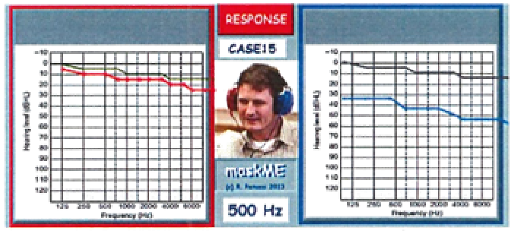
a. Are you able to get a plateau? If so, how wide is it?

____

____

Extra cases for fast workers!

13. Masking bone conduction
Case 15



Use supra-aural headphones– IA is 40dB

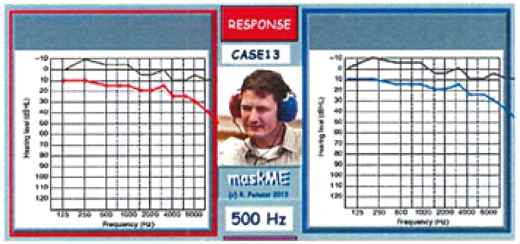
Use the plateau plotter in maskME for this activity

Test the **left** ear **bone** conduction at 500Hz.

Start the masking noise level in the **right** ear at 40dB.

a) Were you able to get a plateau? If so, how wide was it? ____________________

14. Masking bone conduction
Case 13



Use supra-aural headphones– IA is 40dB

Use the plateau plotter in maskME for this activity

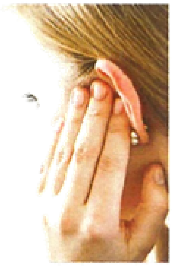
Test the **right** ear **bone** conduction at 4000Hz.

Start masking at 35dB in the **left** ear.

a) Were you able to get a plateau? If so, how wide was it? ____________________

Compare your answers with your neighbour

The occlusion effect



What is it?

An increase in low-frequency sounds when an ear/the ears are blocked.

Like when you block your ears and talk and notice that your voice sounds deeper.

When does it happen in hearing testing?

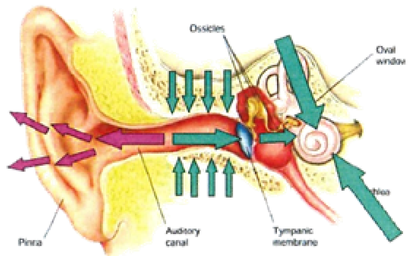
1. When we need to mask the non-test ear during bone conduction – one ear is blocked
2. When we measure air-conduction thresholds – both ears are blocked.

Why does it happen?

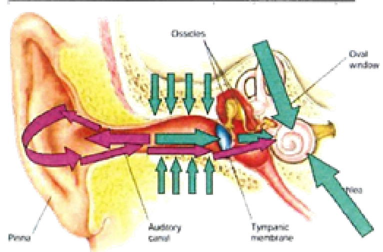
When the ears are unoccluded, some low-frequency sound - 1000Hz and under - is able to leak *out* of the ear canals and into the environment.

This leakage happens in the first stage of bone conduction testing when both ears are unoccluded.

Unoccluded – pink arrows show low frequency sounds escaping out of the ear canal



Occluded – pink arrows show low frequency sounds reflecting back into the cochlea



Bone-conducted test signals vibrate the whole skull. When there is something blocking the non-test ear (like a masking headphone), the sound that normally leaks out is reflected back down the ear canal and into the non-test ear cochlea.

Occluding the ear traps that low frequency sound in, adding to the sound in the cochlea.

This results in more sound reaching the non-test ear cochlea, which means the sound is louder! This gives *better* BC thresholds at the non-test ear cochlea.

NB: Improved BC thresholds due to the occlusion effect are not reflective of better cochlear sensitivity: an ear doesn't start hearing better because it is occluded – it appears to be hearing 'better' simply because there is *more* sound at the cochlea.

Is it a problem?

1. Yes, it is a problem in masked bone conduction testing for 500Hz and 1000Hz. Occluding the non-test ear increases the intensity of a bone-conducted signal in the non-test ear, making it more likely to respond to the test tone than the test ear (by cross-hearing).

2. The occlusion effect is *not* a problem in air conduction testing, even though both ears are occluded with the headphones or insert earphones. In air-conduction testing, there is no comparison between unoccluded and occluded thresholds, and the occlusion effect for air-conduction testing is calibrated into the testing equipment.

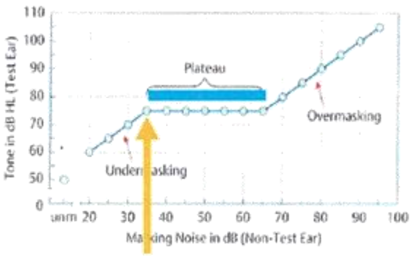
3. The OE is *not* a problem during unoccluded bone conduction testing as nothing occludes the ears.

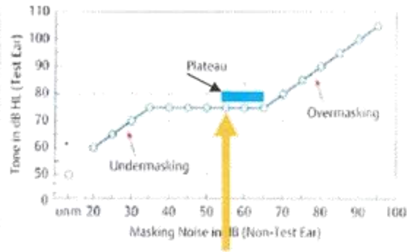
Bone conduction masking and the occlusion effect

The occlusion effect is a problem during masked BC testing because more masking noise (10-20dB) is needed to cover the increase of sound energy in the non-test ear cochlea.

More masking noise is needed to offset the occlusion effect. The starting level masking noise in the non-test ear needs to 'reset' the improvement in BC threshold back to the original unoccluded threshold.

More masking noise always results in reaching the point of overmasking earlier, and therefore results in a shorter plateau width. It may impact the tester's ability to even get a 15dB plateau.





Yellow arrow shows level at which masking starts. Blue line shows width of plateau

Example 1: no extra masking added to compensate for the occlusion effect. Masking noise starts at 35dB. Overmasking starts after 65dB of masking.

Example 2: an extra 20dB of masking is added to compensate for the occlusion effect – masking starts at 55dB. Overmasking starts after 65dB of masking – impossible to get even a 15dB plateau.

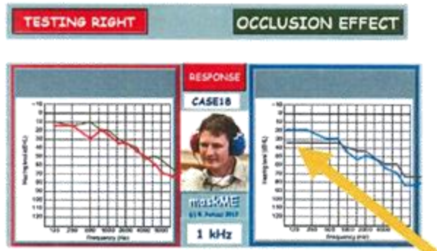
How large is the occlusion effect?

The OE must be added on to the initial masking level in order to effectively mask the non-test ear and eliminate its participation in hearing the test tones to the test ear. In clinical masking, large, 'worst-case scenario' average values are used, which are added onto the initial masking level.

The average size of the occlusion effect varies from 10-20dB depending on whether headphones or insert earphones were used, and on the frequency of the test tone.

maskME shows you how the occlusion effect looks:

Occlusion effect **off**



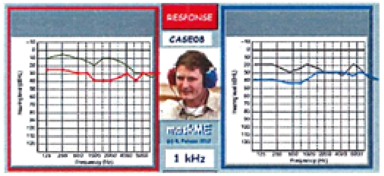
Notice the difference in bone conduction thresholds in the non-test ear (left) at 1000Hz and under.

Occlusion effect **on**

Because the BC thresholds have improved in the non-test ear, cross-over happens at a lower level than without the occlusion effect on.

Q) The occlusion effect for supra-aural headphones at 500Hz is 20dB. If a 500Hz pure-tone is presented to the test ear at 35dB, what level is it *actually* present at in the non-test ear cochlea? ____________

15. Masking BC and the occlusion effect
Case 08



ⓘ Use supra-aural headphones– IA is 40dB

a) Test the left ear's BC threshold at 1000Hz. At what level is there a response? ___________

b) Which ear is responding to this with the OE button off? _________

c) Which ear is responding to this with the OE button on? _________

d) If the non-test ear is occluded, does the tester need to add more or less masking noise to effectively mask the non-test ear?

____

What would this mean for the likelihood of overmasking?

____

____

e) Circle one
Larger occlusion effects result **in longer/shorter/no different** plateau widths.

Compare your answers with your neighbour

Recap! Intended learning outcomes
Circle the correct options and fill in the gaps

1. Understand interaural attenuation

Interaural attenuation is the amount of sound energy that is ____________________ as it travels **through /around** the skull to from one cochlea to the other.

2. Understand cross-hearing

Cross hearing is when the **test ear / non-test ear** hears the test signal before the **non-test ear / test ear.**

3. Understand shadow curves

Shadow curves show ___________-____________. They are the worse ear's **air / bone -** conduction thresholds which mimic the better hearing ear's **air/bone** conduction thresholds.

4. Understand the purpose of masking

The purpose of masking is to eliminate the **test ear / non-test ear's** response to the test tone and get ear specific information.

5. Understand the plateau

Responses during the plateau are from the **test ear/ non-test** ear. During the plateau, the masking noise is considered effective in eliminating the **test ear / non-test ear's** response to the test tone.

6. Understand overmasking

Overmasking occurs when the level of masking noise is intense enough to be heard in the **non-test ear / test ear** and worsen that ear's thresholds. Sometimes overmasking can make it impossible to get an accurate threshold at a particular frequency.

7. Understand how the following affect plateau width

The larger the interaural attenuation, the **shorter / wider** the plateau width.

The larger the occlusion effect, the **shorter / wider** the plateau width.

The larger the conductive component, the **shorter / wider** the plateau width.

Masking – takeaway points

The **purpose** of masking is to get accurate ear-specific information. Masking is the process of presenting a 'white' noise into the non-test ear and varying the level until responses are reliably only coming from the test ear.

Interaural attenuation is the reduction in the amount of skull vibration as sound travels from one cochlea to the other, through the skull via bone conduction mechanisms. IA varies depending on transducer type and type of sound (e.g. pure tone, masking noise, or speech stimuli).

Crossover is the portion of the signal from the test ear that physically reaches the non-test ear (NTE) via interaural attenuation. It may or may not be heard, depending on how well the NTE can hear.

Cross-hearing is when the level at which the sound crosses over is *audible* in the NTE. The NTE cochlea must be sensitive enough to detect the crossed-over sound to be able to respond to it. When cross-hearing is suspected, masked thresholds must be sought.

Air conduction thresholds are masked on a frequency-by-frequency basis when cross-hearing is suspected. It is important to look at the difference in dB between the ears at each frequency, looking for differences of IA or greater. It is particularly important to look at the bone conduction threshold of the better ear and compare it to the air conduction threshold of the worse ear. Compare between air conduction thresholds at each frequency as well as the AC of one ear and BC of the other.

Bone conduction thresholds are masked based on the presence of an air-bone gap of 15dB or more. Masked thresholds will determine whether the ABG represents a true conductive component in the test ear, or if the unmasked bone conduction threshold is coming from the other ear.

A masking **plateau** is reached when increases in masker level do not affect the test ear's ability to respond to the signal at a particular level. This level can be accepted as the test ear's masked threshold once an increase of 20dB in masker noise does not affect the responses. In some situations (e.g. bilateral conductive hearing loss), a plateau of 15dB can be accepted.

The **occlusion effect** occurs when an ear is occluded (e.g. with a headphone on the NTE for masking) and traps more sound in the ear canal. This leads to greater sound energy at the cochlea, which is perceived as a louder sound. This results in BC results appearing better than they are. It must be countered by adding more masking noise to the NTE, which then increases the risk of overmasking

Overmasking happens when the masking sound is strong enough to cross through the head and be heard by the test ear! It can make the test ear's thresholds appear worse than they actually are. Overmasking is most likely to happen in cases of conductive hearing loss.

Masking dilemmas occur when the amount of masking noise needed to effectively elevate the NTE's threshold is strong enough to cross the head and be audible in the test ear, resulting in an overmasking situation. They are most common with bilateral conductive losses, or one ear with a conductive loss and one ear with a sensorineural loss. It can be impossible to get masked thresholds in these situations.

Always ask yourself: is there any chance that the non-test ear can hear the sound presented to the test ear?

WORKBOOK D - NOVICES

Clinical masking workbook

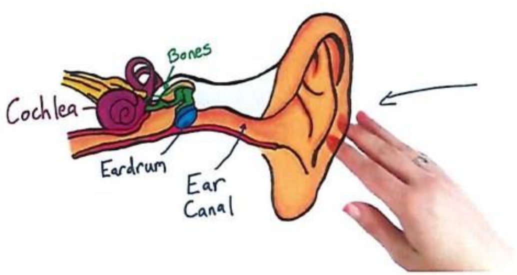
Part 1: Interaural attenuation and cross-hearing

Part 2: Doing masking

Intended learning outcomes

1. Understand interaural attenuation
2. Understand cross-hearing
3. Understand shadow curves
4. Understand the purpose of masking
5. Understand the plateau
6. Understand overmasking
7. Understand how the following affect plateau width
   -interaural attenuation
   -the occlusion effect
   -the size of conductive components

Recap learning outcomes on page 22!



Part 1. Interaural attenuation and cross-hearing

The two cochleas are connected by structures in the head. If a sound is intense enough in one ear, it can also be audible in the other ear.

When you're testing one ear, and the *other* ear responds first, ***cross-hearing*** is happening! This is problematic for testing.

Interaural attenuation **(IA) is how much a sound is attenuated as it travels from one ear to the other through the skull.** It depends on test stimuli (e.g. frequency) and transducer (speaker). For example, the bone conduction vibrator has an IA of 0dB, and IA for air-conduction transducers (supra-aural headphones and insert earphones) varies from 40-75dB.

A small IA (e.g. 0dB) means that 0dB of energy is lost between the cochleas; i.e. when one ear is given a 20dB pure tone sound, 20dB also arrives to the other cochlea.

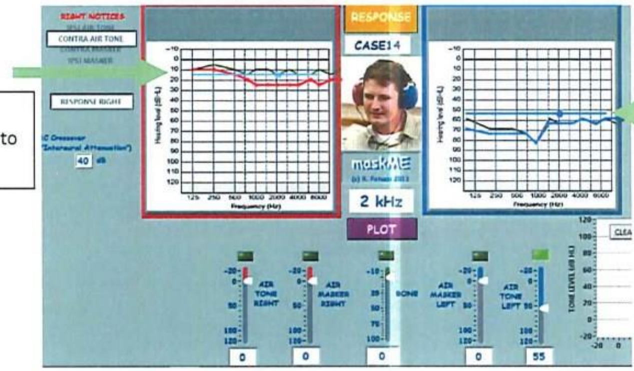
A large IA (e.g. 60dB) means that if one ear is presented with a 70dB pure tone sound, 60dB of it is lost in transmission between the cochleas, and only 10dB of it arrives at the other cochlea after passing through the skull.

Example

1) Find the **left** ear's air conduction threshold at 2000Hz. Use the Air Tone slider to find this out.

Use supra-aural headphones– IA is 40dB

Light blue line = level of crossover to non-test ear



Horizontal blue line = level of signal to test ear

Crossover is the portion of the signal from the test ear that physically reaches the non-test ear cochlea via interaural attenuation. It may or may not be heard, depending on how well the non-test ear can hear.

Cross-hearing is when the level at which the sound crosses over is *audible* in the non-test ear . The non-test ear cochlea must be sensitive enough to detect the crossed-over sound to be able to respond to it.

Cross-hearing is what we need to consider when doing hearing testing!

1. **Cross-hearing and interaural attenuation**
   Case 36 in maskME. Right ear normal and dead left ear

No thresholds in the audiogram = no responses at all (i.e. dead ear!)

Ask yourself: is there an obvious better ear? If one ear is much better than the other, it is possible that cross-hearing may occur.

a) Test the **right** ear air conduction threshold (using the Air Tone slider) at 4000Hz.
What is the lowest level (in dB) at which there is a response from either ear?

____

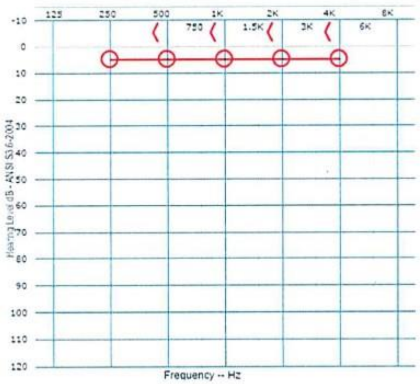
b) Which ear is responding? Right/left

c) Test the **left** ear air conduction threshold at 4000Hz. At what level is there a response (from either ear)? ____________
Plot that on the audiogram below using a cross symbol.

d) Which ear responds at this level? Right/left

If the non-test ear responds before the test ear, masking will be required to get separate ear information

e) Complete the **left** ear air conduction results for 500, 1000 and 2000Hz on the audiogram below. Use cross symbols.



Compare your answers with your neighbour

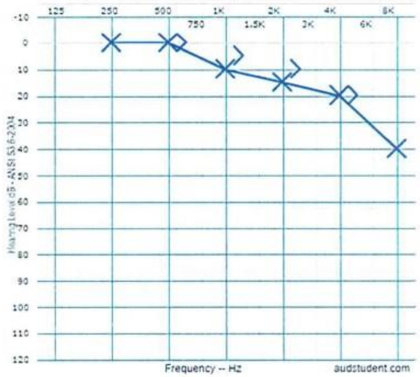
	AIR CONDUCTION UNMASKED	AIR CONDUCTION MASKED	BONE CONDUCTION UNMASKED	BONE CONDUCTION MASKED
RIGHT	O	● or △	<	[
LEFT	X	Ι or □	>	]

This is called the *shadow curve*: the unmasked left ear thresholds shadow the right ear BC thresholds.

Cross-hearing and interaural attenuation
Shadow curves

2. Case 34 in maskME. The **right** ear is completely dead. Test the **right** ear's air conduction thresholds using the Air Tone slider for 500, 1000, 2000 and 4000Hz.

   Mark the quietest levels for each frequency where the response button lights up, *even if it is from the* ***left*** *ear.* Mark them with open circles.

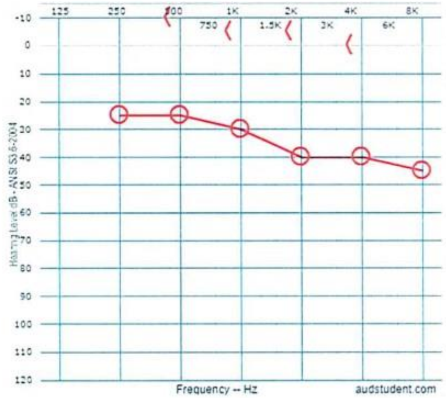


Use supra-aural headphones– IA is 40dB

	AIR CONDUCTION UNMASKED	AIR CONDUCTION MASKED	BONE CONDUCTION UNMASKED	BONE CONDUCTION MASKED
RIGHT	O	● or △	<	[
LEFT	X	Ι or □	>	]

3. Case 09 in maskME. The **left** ear is completely dead. Test the **left** ear's air conduction thresholds using the Air Tone slider for 500, 1000, 2000 and 4000Hz.

Mark the quietest levels where the response button lights up, *even if it is from the* ***right*** *ear.* Mark them with crosses.



Use supra-aural headphones– IA is 40dB

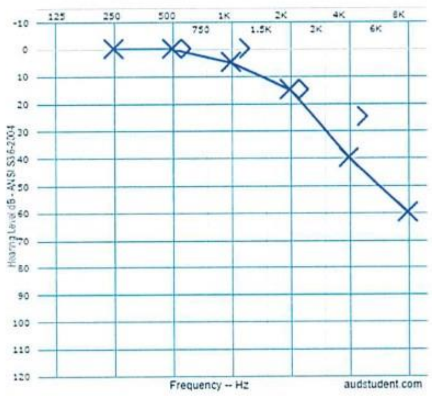
Compare your shadow curves with your neighbour

Compare your shadow curves with your neighbour

Cross-hearing and interaural attenuation
Shadow curves *continued*

4. Case 07 in maskME. The **right** ear is completely dead. Test the **right** ear's air conduction thresholds using the Air Tone slider for 500, 1000, 2000 and 4000Hz.

   Mark the quietest levels where the response button lights up, *even if it is from the **left** ear.* Mark them with open circles.



Use insert-earphones – change the interaural attenuation to 60dB

	AIR CONDUCTION UNMASKED	AIR CONDUCTION MASKED	BONE CONDUCTION UNMASKED	BONE CONDUCTION MASKED
RIGHT	O	● or △	<	[
LEFT	X	⧗ or □	>	]

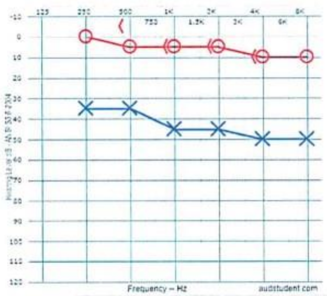
Cross-hearing and interaural attenuation

Shadow curves

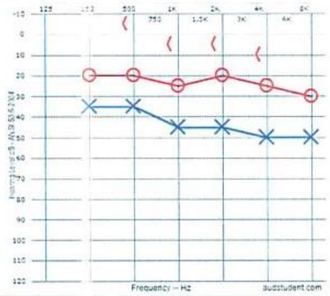
Shadow curves happen when the sound to the bad ear is loud enough to overcome interaural attenuation and be heard by the good ear (the non-test ear).

Shadow curves show cross-hearing! Not every situation with cross-hearing will have a shadow curve, but some do – so they're important to recognise.

Example 1: right ear has normal hearing and left ear is totally dead



Example 2: right ear has a conductive hearing loss (gaps between AC and BC thresholds) and left ear is totally dead



	AIR CONDUCTION UNMASKED	AIR CONDUCTION MASKED	BONE CONDUCTION UNMASKED	BONE CONDUCTION MASKED
RIGHT	O	● or △	<	[
LEFT	X	⧗ or □	>	]

The left ear is showing a shadow curve, mimicking the shape of the right ear bone conduction (BC) hearing thresholds.

The shadow curves for both examples are **exactly the same**, despite a difference in the right ear's air conduction (AC) thresholds.

Unmasked thresholds seen in shadow curves will likely need masking!

Interaural attenuation is a bone conduction mechanism: the difference in dB between the ears is mostly lost *through* th head, not around it (via the air).

Q) Do shadow curves mimic the **bone** conduction thresholds or **air** conduction thresholds of the better ear? ________

5. <u>Bone conduction testing</u>

Cross-hearing and interaural attenuation
Case 01.

ⓘ IA for the bone conduction vibrator is 0dB – but you **don't** need to change the IA figure in maskME

a) Test the **left** ear BC threshold at 1000Hz. At what level is there a response? __________

b) What ear is responding at that level? Right/left

c) What is the true **left** ear's BC threshold at 1000Hz? (look at the black line!) __________

d) Test the **right** ear bone conduction at 1000Hz. At what level is there a response?

____

e) What is the difference between the left and right unmasked bone conduction thresholds? ((a) and (d)) ______________

ⓘ IA for the bone-conduction vibrator is 0dB! This means that you can present 50dB signal to the right ear and the left ear will also detect a 50dB signal.

Part 2: doing masking

When cross-hearing happens (the non-test ear (NTE) responds before the test ear (TE)), masking is needed to find out the TE's actual threshold. Cross-hearing can happen in both air-conduction and bone-conduction testing. So, we can mask AC or BC thresholds.

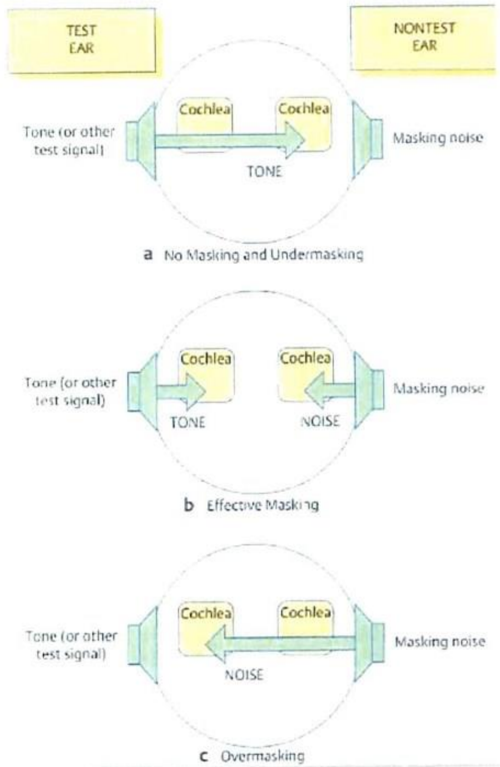
Masking noise is a type of white noise that helps to separate the ears by 'keeping the non-test ear busy' so that it can't respond to the test signal. It 'keeps it busy' by worsening the NTE's threshold so that it is unable to hear the test signal.

Masking noise is always presented to the NTE using a headphone or insert earphone, never the bone conductor.

Masking noise is increased in 10dB steps while responses to the test signal are checked. This technique is called Hood's plateau method of masking.

When there are responses despite increases in masking noise, the response is coming from the TE cochlea. This is the *plateau.*

3 stages of masking and the plateau curve



Undermasking

Reponses are from the non-test ear

Not enough masking noise to worsen the non-test ear threshold

Plateau (*effective masking*)

Reponses are from the test ear at true threshold

Masking sound is sufficiently strong to worsen the non-test ear threshold, and eliminate its ability to respond to signals to the test ear

Overmasking

Responses are from test ear but not at true threshold – at a worse threshold

Masking sound is intense enough to be audible in the test ear, worsening the test ear's ability to detect the test signal

The plateau curve

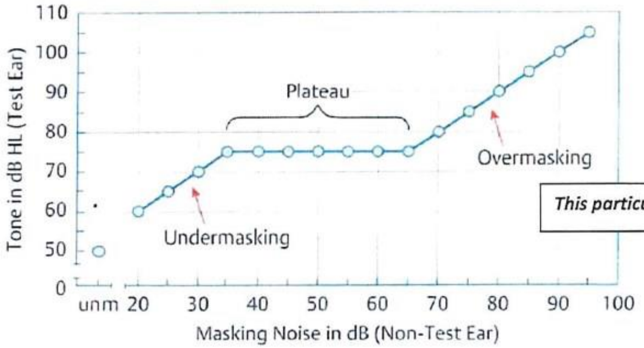


Image from Gelfand 2015 p.260

This particular plateau is 30dB wide

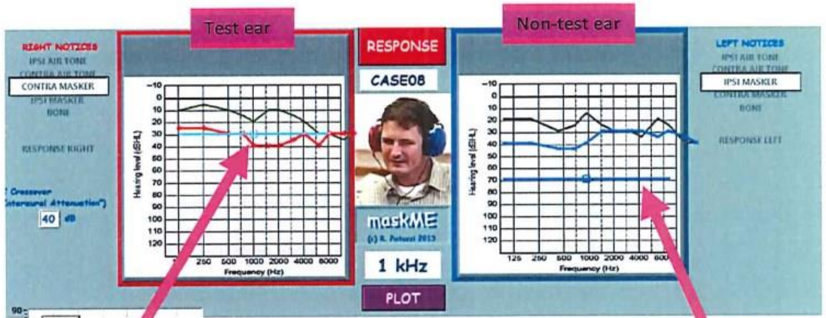
Overmasking

The louder the masking noise is, the sooner overmasking can happen.

Overmasking shortens the plateau width.

If overmasking happens before you can even get a 15dB plateau, you cannot mask that threshold. This is a **masking dilemma**, and it is impossible to know the true threshold.

Overmasking in maskME – what it looks like



Light blue line = level of masking noise in test ear

Because the light blue line is below (more intense than) the bone conduction threshold of the test ear, overmasking is happening

Dark blue line = masker is in non-test ear at 70dB

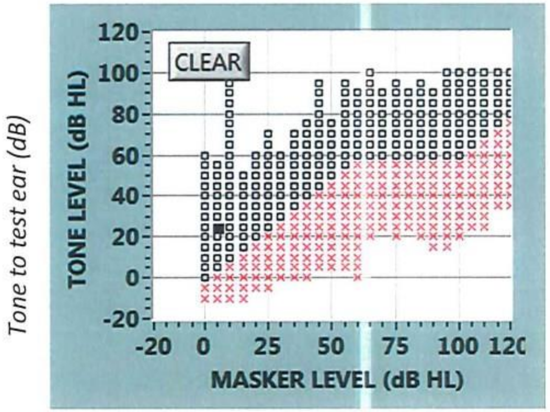
The plateau in maskME

Class demonstration – Case 01, testing the left ear bone conduction threshold at 2000Hz

□ indicates a response – but could be from either ear

X indicates *no* response from either ear

Tone to test ear (dB)



This plateau is 40dB wide before overmasking starts

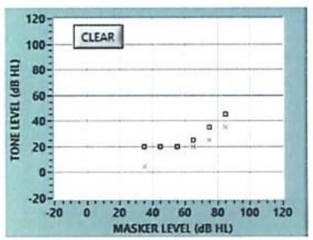
Masking sound to non-test ear – the better ear (dB)

The plateau curve shows us that the test ear's true threshold is at 60dB.

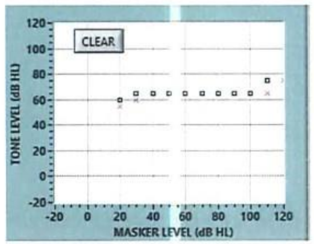
In some cases, such as for conductive hearing losses (with air-bone gaps of 15dB or more), a short plateau of 15dB can be accepted. Always try to get a plateau!

A plateau of 5dB or 10dB is **not enough** – responses to the test tone cannot be accepted as coming from the test ear until there is a plateau of at least 15dB, usually 20dB.

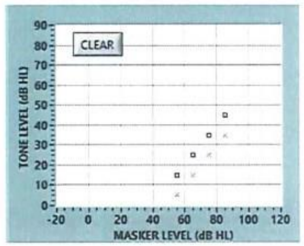
Examples of different plateau widths in maskME



30dB plateau width



70dB plateau width

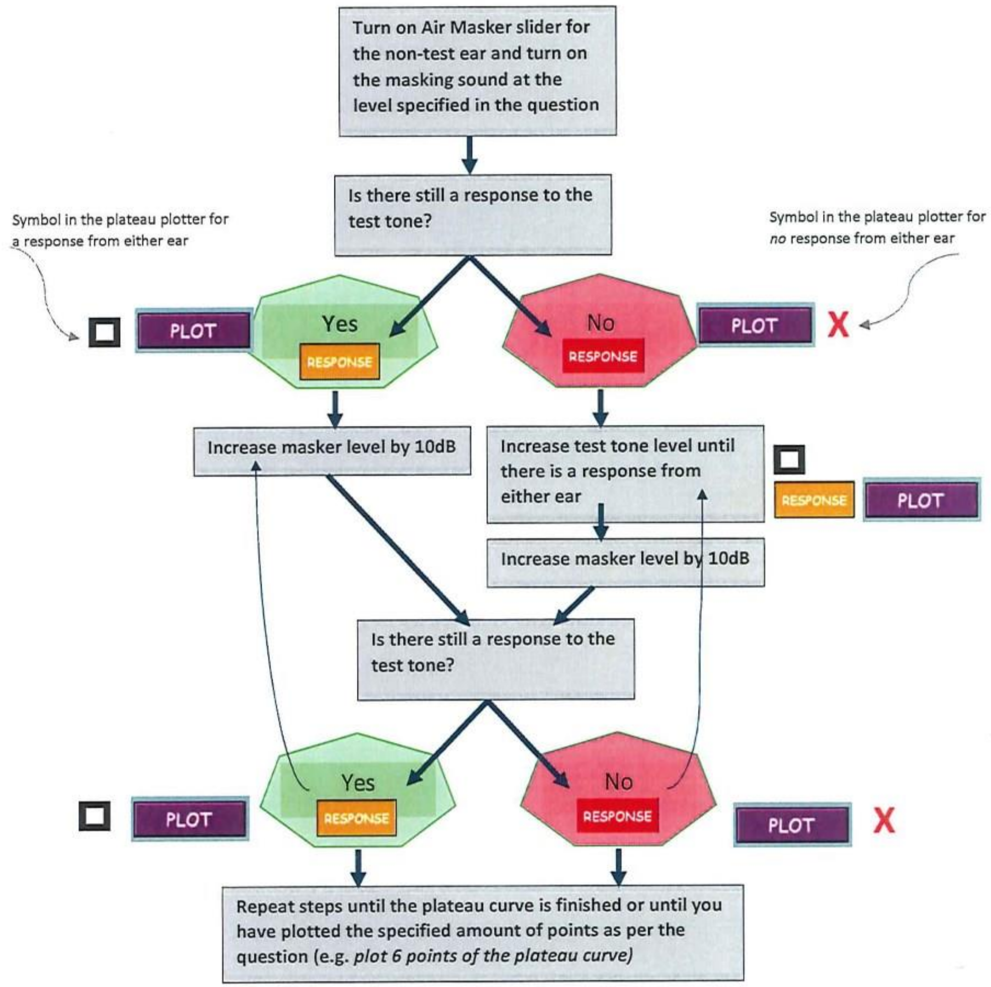


No plateau! Sometimes it is impossible to get a plateau of even 15dB

The Hood masking procedure!

The procedure is done when cross-hearing is occurring: when the non-test ear hears the test tone before the test ear.

The goal is to find a plateau of at least 20dB to establish the true threshold of the test ear.



If you cannot get a 20dB plateau to establish threshold (i.e. 2 increases of 10dB in masking noise, try to get a 15dB plateau to establish threshold

Every time there is a response or *non-*response, use the Plot button to plot the plateau curve! PLOT

6. Air conduction masking and the plateau
Case 14

Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's air conduction (AC) threshold at 2000Hz. What level (dB) is there a response, from either ear? ____________

b) What is the **right** ear's bone conduction (BC) threshold at 2000Hz? ____________

c) What is the difference between (a) and (b)? ____________

d) How does this figure compare to the interaural attenuation? ____________

Go back to testing the left ear AC and find its threshold again– turn off the bone conduction slider!

e) Now turn on the **right** air masking button. How loud do you have to make the masking noise to stop the cross-hearing response? ____________

Use the plateau plotter in maskME for the following activity PLOT

f) Increase the level of the **left** AC tone until there is a response and use the Plot button to plot the response.

Every time the **left** ear (the test ear) responds, increase the masking noise in the **right** ear by 10dB. Plot each point.

Every time the **right** ear (the non-test ear) responds, increase the AC tone until there is a response. Plot each point.

Continue to plot responses **and** non-responses until you have been able to obtain a 20dB plateau (i.e. an increase of 20dB in masking noise with no change in threshold in the left ear)

This masking procedure is called the Hood Procedure.

g) What is the **left** ear's true (i.e. masked) AC threshold at 2000Hz? ____________

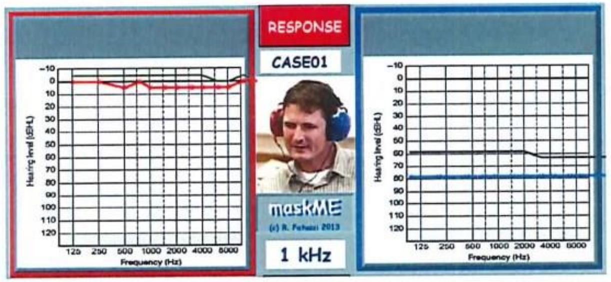
h) Continue to increase the masking noise and tone level and plot the results. What happens after the plateau?

Overmasking occurs when the masking noise is audible in the test ear cochlea, raising its threshold, and interfering with its ability to respond at its true threshold.

____

7. Air conduction masking and the plateau

Case 01



ⓘ Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's air conduction (AC) threshold at 1000Hz. What level (dB) is there a response, from either ear? ______________

b) Turn on masking in the **right** ear at 25dB.

c) Plot responses and non-responses on the plateau plotter.

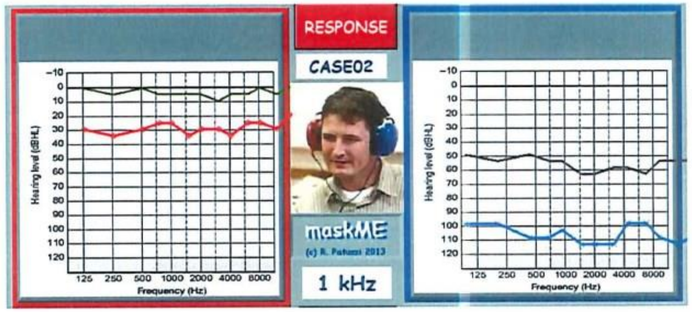
*Every time the **left** ear (the test ear) responds, increase the masking noise in the **right** ear by 10dB. Plot each point.*

*Every time the **right** ear (the non-test ear) responds, increase the AC tone until there is a response. Plot each point.*

d) What is the **left** ear's true (i.e. masked) AC threshold at 1000Hz? ____________

8. Air conduction masking and the plateau

Case 02



ⓘ Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's air conduction (AC) threshold at 1000Hz. What level (dB) is there a response, from either ear? ______________

b) Turn on masking in the **right** ear at 45dB.

c) Plot responses and non-responses on the plateau plotter.

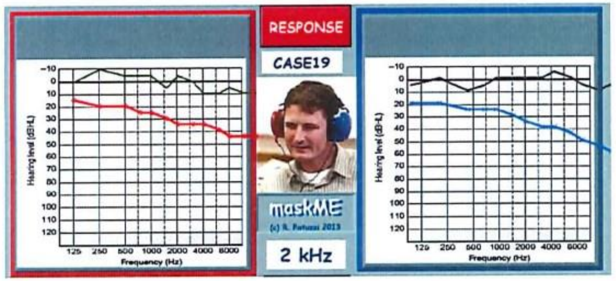
*Every time the **left** ear (the test ear) responds, increase the masking noise in the **right** ear by 10dB. Plot each point.*

*Every time the **right** ear (the non-test ear) responds, increase the AC tone until there is a response. Plot each point.*

d) What is the **left** ear's true (i.e. masked) AC threshold at 1000Hz? ____________

9. **Masking bone conduction and differences in interaural attenuation**

Case 19



Use the plateau plotter in maskME for the following activities

*** Ensure IA is set to 40dB for supra-aural headphones.**

Test the left ear BC threshold at 1000Hz.

Start the masking noise at 45dB in the right ear and plot the plateau curve until you reach 120dB of masking noise.

a) How wide is the plateau? __________

b) At what masking level does overmasking start? __________

> A plateau must be at least 15dB wide to be considered a plateau! If it is less than 15dB, we cannot trust that the responses are from the test ear.

*** Change IA to 60dB for insert-earphones**

Test the left ear BC threshold at 1000Hz

Start masking at 45dB and plot the plateau curve until you reach 120dB of masking.

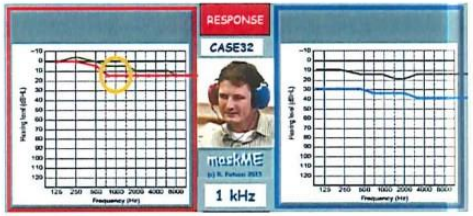
c) How wide is the plateau? __________

d) At what masking level does overmasking start? __________

> e) Circle one
> Larger interaural attenuation values result **in longer/shorter/no different** plateau widths.

Masking bone conduction and air-bone gaps

10. **Case 32**



> Use supra-aural headphones– IA is 40dB

a) How large is the conductive component (difference between AC and BC thresholds, i.e. the air-bone gap) in the right ear at 500Hz? ______________

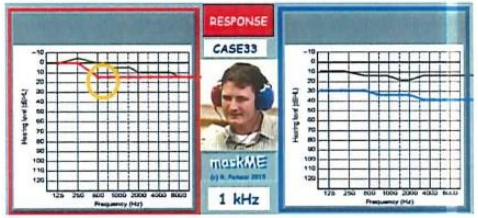
Find the unmasked left BC threshold at 500Hz. The unmasked threshold is the quietest level at which there is a response *from either ear*.

Start masking at 30dB in the right ear and plot the plateau curve.

Plot two points of overmasking

b) How wide (in dB) is the plateau before overmasking starts? __________

11. **Case 33**



a) How large is the conductive component (difference between AC and BC threshold in the right ear at 500Hz? ______________

Find the unmasked left BC threshold at 500Hz and then start masking at 45dB in the non-test ear and plot the plateau curve.

More masking noise is required (than for Case 32) because the noise will be attenuated by the amount of the conductive component, but it still must reach the non-test ear cochlea at the same level as in Case 32.

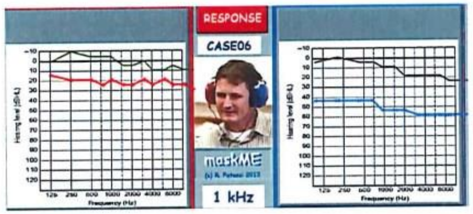
Plot two points of overmasking

b) How wide (in dB) is the plateau before overmasking starts? __________

> c) Circle one
> Larger conductive components result **in longer/shorter/no different** plateau widths.

Case 33 (Question 11) shows a **masking dilemma,** where it is not possible to even get a 15dB plateau (the minimum width acceptable). This occurs when the minimum amount of masking needed in the non-test ear is strong enough to be audible in the test ear, resulting in overmasking happening almost immediately.

12. Air conduction masking
Case 06



Use supra-aural headphones– IA is 40dB

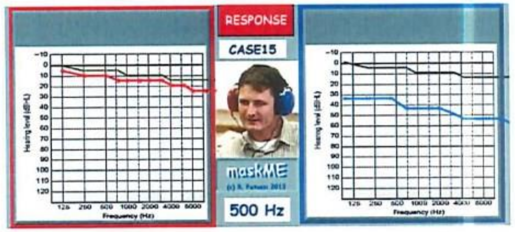
Use the plateau plotter in maskME for the following activity

1. Test the **right** ear AC threshold at 2000Hz and leave the AC slider at threshold, i.e. the quietest level of response *from either ear*.
2. Start masking noise in the **left** ear at 65dB
3. Plot at least 8 points of responses and non-responses
4. Are you able to get a plateau? If so, how wide is it?

____

____

13. Masking bone conduction
Case 15



Use supra-aural headphones– IA is 40dB

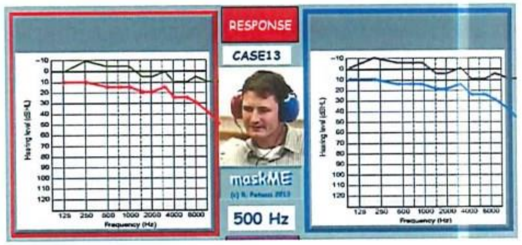
Use the plateau plotter in maskME for this activity

Test the **left** ear **bone** conduction at 500Hz.

Start the masking noise level in the **right** ear at 40dB.

a) Were you able to get a plateau? If so, how wide was it? ________________

14. Masking bone conduction
Case 13



Use supra-aural headphones– IA is 40dB

Use the plateau plotter in maskME for this activity

Test the **right** ear **bone** conduction at 4000Hz.

Start masking at 35dB in the **left** ear.

a) Were you able to get a plateau? If so, how wide was it? ________________

Compare your answers with your neighbour

The occlusion effect

What is it?

An increase in low-frequency sounds when an ear/the ears are blocked.

Like when you block your ears and talk and notice that your voice sounds deeper.

When does it happen in hearing testing?

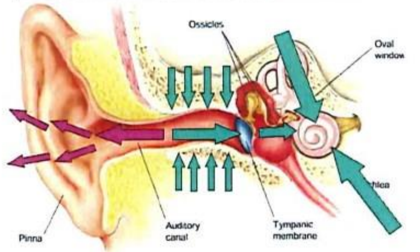
1. When we need to mask the non-test ear during bone conduction – one ear is blocked
2. When we measure air-conduction thresholds – both ears are blocked.

Why does it happen?

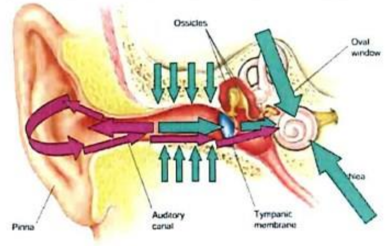
When the ears are unoccluded, some low-frequency sound - 1000Hz and under - is able to leak *out* of the ear canals and into the environment.

This leakage happens in the first stage of bone conduction testing when both ears are unoccluded.

Unoccluded – pink arrows show low frequency sounds escaping out of the ear canal



Occluded – pink arrows show low frequency sounds reflecting back into the cochlea



Bone-conducted test signals vibrate the whole skull. When there is something blocking the non-test ear (like a masking headphone), the sound that normally leaks out is reflected back down the ear canal and into the non-test ear cochlea.

Occluding the ear traps that low frequency sound in, adding to the sound in the cochlea.

This results in more sound reaching the non-test ear cochlea, which means the sound is louder! This gives *better* BC thresholds at the non-test ear cochlea.

NB: Improved BC thresholds due to the occlusion effect are not reflective of better cochlear sensitivity: an ear doesn't start hearing better because it is occluded – it appears to be hearing 'better' simply because there is *more* sound at the cochlea.

Is it a problem?

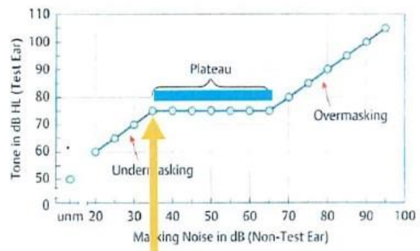
1. Yes, it is a problem in masked bone conduction testing for 500Hz and 1000Hz. Occluding the non-test ear increases the intensity of a bone-conducted signal in the non-test ear, making it more likely to respond to the test tone than the test ear (by cross-hearing).
2. The occlusion effect is *not* a problem in air conduction testing, even though both ears are occluded with the headphones or insert earphones. In air-conduction testing, there is no comparison between unoccluded and occluded thresholds, and the occlusion effect for air-conduction testing is calibrated into the testing equipment.
3. The OE is *not* a problem during unoccluded bone conduction testing as nothing occludes the ears.

Bone conduction masking and the occlusion effect

The occlusion effect is a problem during masked BC testing because more masking noise (10-20dB) is needed to cover the increase of sound energy in the non-test ear cochlea.

More masking noise is needed to offset the occlusion effect. The starting level masking noise in the non-test ear needs to 'reset' the improvement in BC threshold back to the original unoccluded threshold.

More masking noise always results in reaching the point of overmasking earlier, and therefore results in a shorter plateau width. It may impact the tester's ability to even get a 15dB plateau.



Yellow arrow shows level at which masking starts. Blue line shows width of plateau

Example 1: no extra masking added to compensate for the occlusion effect. Masking noise starts at 35dB. Overmasking starts after 65dB of masking.

Example 2: an extra 20dB of masking is added to compensate for the occlusion effect – masking starts at 55dB. Overmasking starts after 65dB of masking – impossible to get even a 15dB plateau.

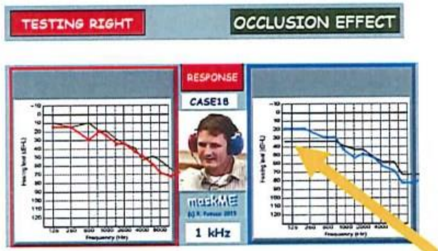
How large is the occlusion effect?

The OE must be added on to the initial masking level in order to effectively mask the non-test ear and eliminate its participation in hearing the test tones to the test ear. In clinical masking, large, 'worst-case scenario' average values are used, which are added onto the initial masking level.

The average size of the occlusion effect varies from 10-20dB depending on whether headphones or insert earphones were used, and on the frequency of the test tone.

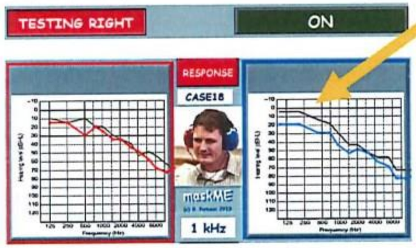
maskME shows you how the occlusion effect looks:

Occlusion effect **off**



Notice the difference in bone conduction thresholds in the non-test ear (left) at 1000Hz and under.

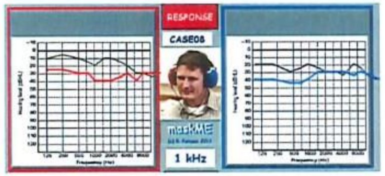
Occlusion effect **on**



Because the BC thresholds have improved in the non-test ear, cross-over happens at a lower level than without the occlusion effect on.

Q) The occlusion effect for supra-aural headphones at 500Hz is 20dB. If a 500Hz pure-tone is presented to the test ear at 35dB, what level is it *actually* present at in the non-test ear cochlea? ___________

15. Masking BC and the occlusion effect
Case 08



Use supra-aural headphones– IA is 40dB

a) Test the **left** ear's BC threshold at 1000Hz. At what level is there a response? ___________

b) Which ear is responding to this with the OE button off? __________

c) Which ear is responding to this with the OE button on? __________

d) If the non-test ear is occluded, does the tester need to add more or less masking noise to effectively mask the non-test ear?

____

What would this mean for the likelihood of overmasking?

____

____

c) Circle one
Larger occlusion effects result **in longer/shorter/no different** plateau widths.

Recap! Intended learning outcomes

Circle the correct options and fill in the gaps

Compare your answers with your neighbour

1. Understand interaural attenuation

Interaural attenuation is the amount of sound energy that is ____________________ as it travels **through /around** the skull to from one cochlea to the other.

2. Understand cross-hearing

Cross hearing is when the **test ear / non-test ear** hears the test signal before the **non-test ear / test ear.**

3. Understand shadow curves

Shadow curves show ____________-____________. They are the worse ear's **air / bone -** conduction thresholds which mimic the better hearing ear's **air/bone** conduction thresholds.

4. Understand the purpose of masking

The purpose of masking is to eliminate the **test ear / non-test ear's** response to the test tone and get ear specific information.

5. Understand the plateau

Responses during the plateau are from the **test ear/ non-test** ear. During the plateau, the masking noise is considered effective in eliminating the **test ear / non-test ear's** response to the test tone.

6. Understand overmasking

Overmasking occurs when the level of masking noise is intense enough to be heard in the **non-test ear / test ear** and worsen that ear's thresholds. Sometimes overmasking can make it impossible to get an accurate threshold at a particular frequency.

7. Understand how the following affect plateau width

The larger the interaural attenuation, the **shorter / wider** the plateau width.

The larger the occlusion effect, the **shorter / wider** the plateau width.

The larger the conductive component, the **shorter / wider** the plateau width.

Masking – takeaway points

The **purpose** of masking is to get accurate ear-specific information. Masking is the process of presenting a 'white' noise into the non-test ear and varying the level until responses are reliably only coming from the test ear.

Interaural attenuation is the reduction in the amount of skull vibration as sound travels from one cochlea to the other, through the skull via bone conduction mechanisms. IA varies depending on transducer type and type of sound (e.g. pure tone, masking noise, or speech stimuli).

Crossover is the portion of the signal from the test ear that physically reaches the non-test ear (NTE) via interaural attenuation. It may or may not be heard, depending on how well the NTE can hear.

Cross-hearing is when the level at which the sound crosses over is *audible* in the NTE. The NTE cochlea must be sensitive enough to detect the crossed-over sound to be able to respond to it. When cross-hearing is suspected, masked thresholds must be sought.

Air conduction thresholds are masked on a frequency-by-frequency basis when cross-hearing is suspected. It is important to look at the difference in dB between the ears at each frequency, looking for differences of IA or greater. It is particularly important to look at the bone conduction threshold of the better ear and compare it to the air conduction threshold of the worse ear. Compare between air conduction thresholds at each frequency as well as the AC of one ear and BC of the other.

Bone conduction thresholds are masked based on the presence of an air-bone gap of 15dB or more. Masked thresholds will determine whether the ABG represents a true conductive component in the test ear, or if the unmasked bone conduction threshold is coming from the other ear.

A masking **plateau** is reached when increases in masker level do not affect the test ear's ability to respond to the signal at a particular level. This level can be accepted as the test ear's masked threshold once an increase of 20dB in masker noise does not affect the responses. In some situations (e.g. bilateral conductive hearing loss), a plateau of 15dB can be accepted.

The **occlusion effect** occurs when an ear is occluded (e.g. with a headphone on the NTE for masking) and traps more sound in the ear canal. This leads to greater sound energy at the cochlea, which is perceived as a louder sound. This results in BC results appearing better than they are. It must be countered by adding more masking noise to the NTE, which then increases the risk of overmasking

Overmasking happens when the masking sound is strong enough to cross through the head and be heard by the test ear! It can make the test ear's thresholds appear worse than they actually are. Overmasking is most likely to happen in cases of conductive hearing loss.

Masking dilemmas occur when the amount of masking noise needed to effectively elevate the NTE's threshold is strong enough to cross the head and be audible in the test ear, resulting in an overmasking situation. They are most common with bilateral conductive losses, or one ear with a conductive loss and one ear with a sensorineural loss. It can be impossible to get masked thresholds in these situations.

Always ask yourself: is there any chance that the non-test ear can hear the sound presented to the test ear?

Appendix H: PowerPoint presentations

MASKING A

20/12/2018

MASKING

- Please sign consent forms and leave them on your desk
- Leave computers logged in as they are

- 1.30-3.30pm with a break in the middle

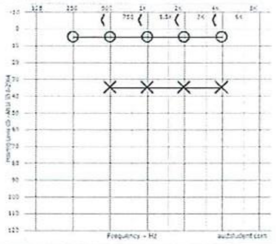
Quiz

- 15 minutes
- Write your ID number
- Return to me when done

Part 1

Interaural attenuation and cross-hearing

Q1i – shadow curve

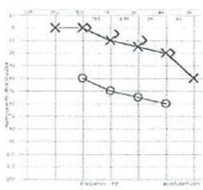


Shadow curves

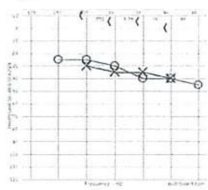
- Page 4
- 5 minutes

Shadow curves

Q2

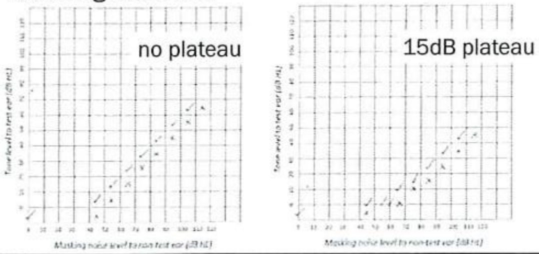


Q3

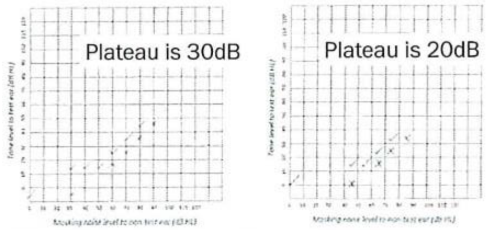


MASKING A

Q13 – masking BC, the plateau and the masking dilemma



Q14 and 15



Quiz 2 and questionnaire

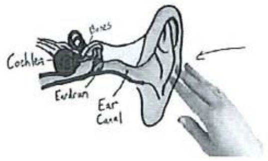
- Student ID on quiz only, please!
- The questionnaire is anonymous
- Collect your voucher on your way out!

- Thank you!

MASKING B

MASKING

1. Interaural attenuation
2. Cross-hearing
3. Shadow curves
4. The purpose of masking
5. The plateau
6. Overmasking
7. How the following affect plateau width:
-interaural attenuation
-the occlusion effect
-the size of conductive component



Page 2 of your workbooks

Part 1

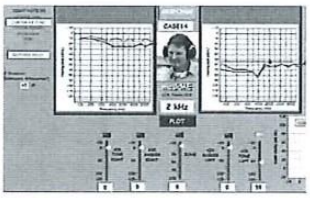
Cross-hearing is when the non-test ear hears the test tone before the test ear.

Interaural attenuation is how much sound is lost as a sound travels from one ear to the other through the head

IA: 40dB IA: 60dB IA: 0dB

maskME demo

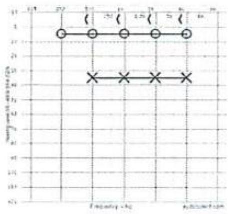
Page 2
Find the **left** ear's air conduction threshold at 2000Hz. Use the Air Tone slider to find this out.



Question 1
Case 36

Do together as a class

1e)

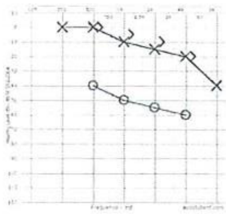


Shadow curves

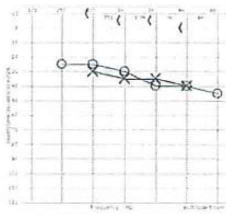
- Page 4-5
- 10 minutes

Shadow curves

Q2



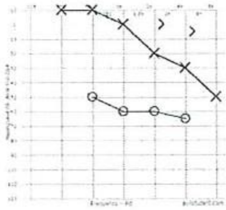
Q3



MASKING B

Shadow curves

Q4

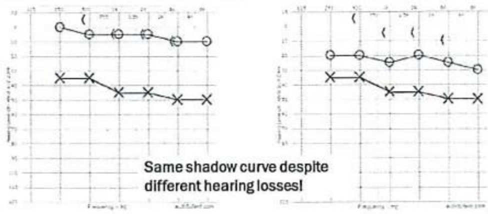


Page 6

Shadow curves

Example 1: right ear has normal hearing and left ear is totally dead

Example 2: right ear has a conductive hearing loss and left ear is totally dead

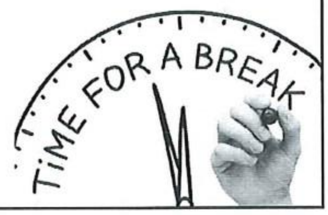


Q5
Bone conduction testing

IA for the bone conduction vibrator is 0dB – but you don't need to change the IA figure in maskME

Break!

10 minutes



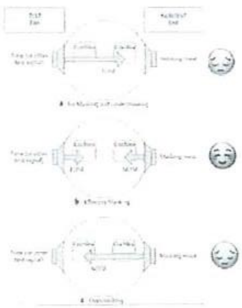
Part 2: doing masking

The goal of masking is to get ear specific results.

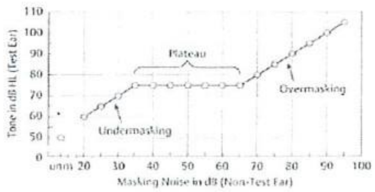
Masking noise is increased in 10dB steps while responses to the test signal are checked.

When there are consistent responses to the test signal *despite* increases in masking noise, a **plateau** has been achieved.

The plateau tells us the true level of hearing from the test ear.



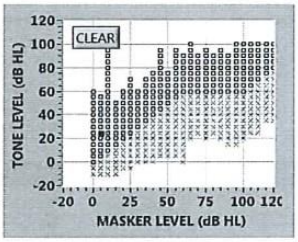
Doing masking
The plateau curve

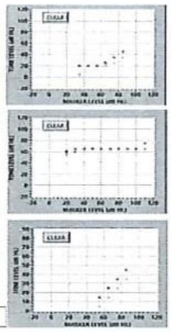


MASKING B

The plateau in maskME

Tone to test ear (dB)

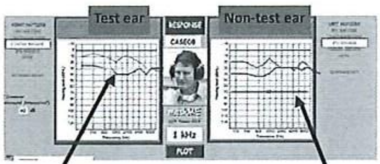




Masking sound to non-test ear – the better ear (dB)

Case 01 LE BC 2000Hz

Overmasking in maskME



Light blue line = level of masking noise in test ear

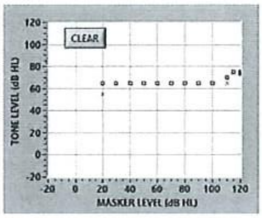
Because the light blue line is below (more intense than) the bone conduction threshold – overmasking is happening

Dark blue line = masker is in non-test ear at 70dB

Doing masking
Workbook activities

- Q6 – 14
- Do many as you can do!
- 25 minutes

Question 6 answer
Case 14



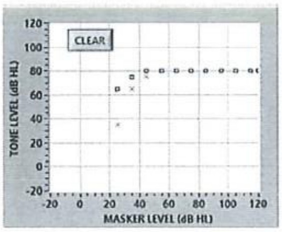
g) What is the left ear's true threshold at 2000Hz?

65dB

h) What happens after the plateau?

Overmasking starts

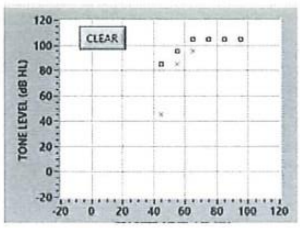
Question 7 answer
Case 01



g) What is the left ear's true threshold at 1000Hz?

80dB

Question 8
Case 02



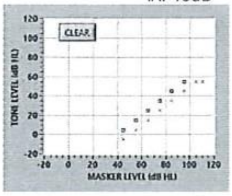
d) What is the left ear's true threshold at 1000Hz?

105dB

MASKING B

Question 9 - Case 19

IA: 40dB



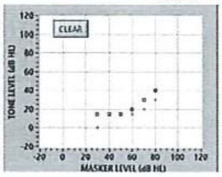
IA: 60dB

8b) No plateau
8c) Overmasking starts at 45dB – immediately

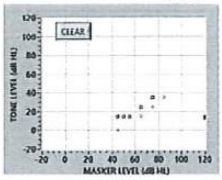
8e) 30dB plateau width
8f) Overmasking starts at 75dB of masking

Question 10 and 11 – Case 32 and 33

Case 32



Case 33



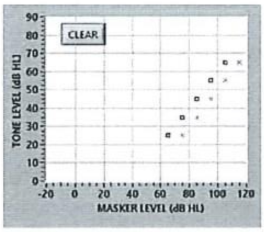
9a) 5dB

9b) 30dB

10a) 15dB

10b) 10dB – not a plateau

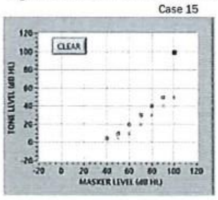
Question 12 – Case 6



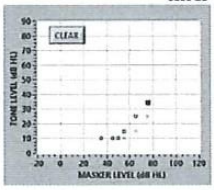
4. No – you can't get a plateau in this case!

Question 13 and 14 – Case 15 and 13

Case 15



Case 13



13a) No – you can't get a plateau in this case!

14a) Yes, you can get a 15dB plateau.

The occlusion effect

What is it?

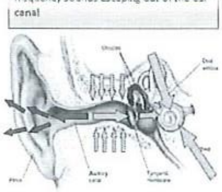
- An increase in low-frequency sounds when an ear/the ears are blocked.

When does it happen in hearing testing?

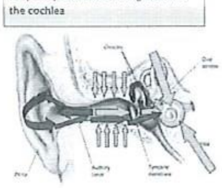
- When we need to mask the non-test ear during bone conduction – one ear is blocked.
- When we measure air-conduction thresholds – both ears are blocked.

The occlusion effect

Unoccluded – pink arrows show low frequency sounds escaping out of the ear canal



Occluded – pink arrows show low frequency sounds reflecting back into the cochlea



MASKING B

The occlusion effect

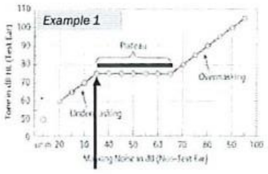
Is it a problem?

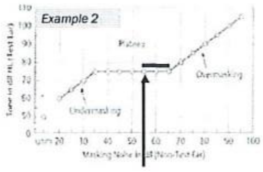
- Yes, for low-frequency bone-conduction testing
- Occluding the NTE increases the intensity of a bone-conducted signal
- =cross-hearing more likely

Page 19

The occlusion effect and masking

- More masking noise is needed to offset the occlusion effect
- More masking noise always results in reaching the point of overmasking earlier!





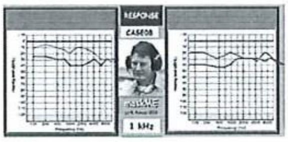
The occlusion effect in maskME

maskME demo

Page 21

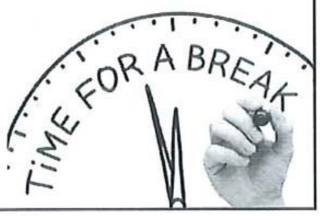
Last workbook activity! Question 15

Case 08



Break

- Until 11.30am!

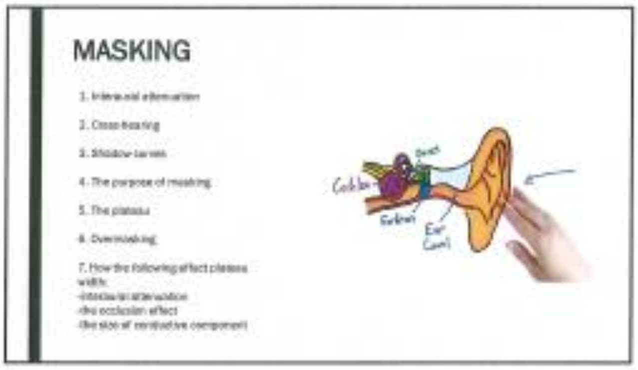


Quiz and questionnaire *Until 12pm*

- Student ID on quiz *only*, please!
- The questionnaire is anonymous
- Please leave your workbooks on the desk
- Collect your voucher on your way out!

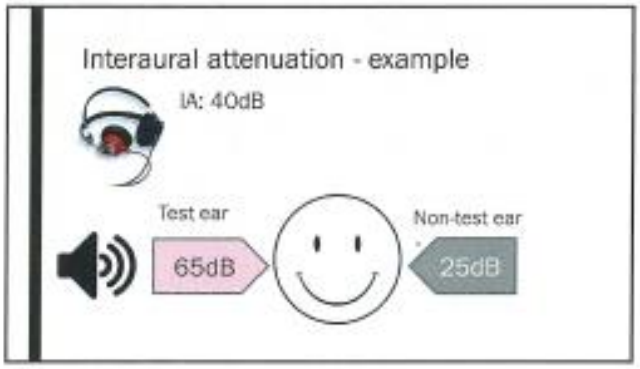
Thank you!

MASKING C

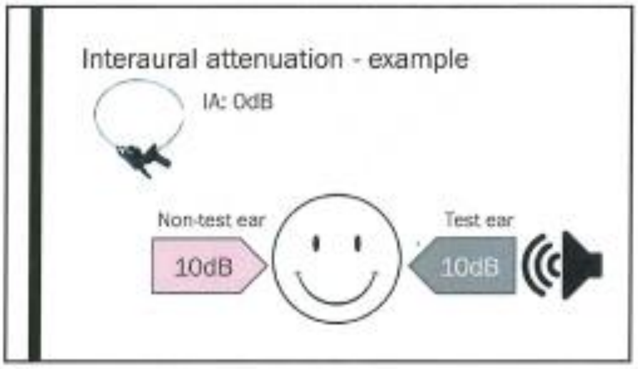


MASKING
4. The purpose of masking
5. The plateau
6. Overmasking
-the occlusion effect

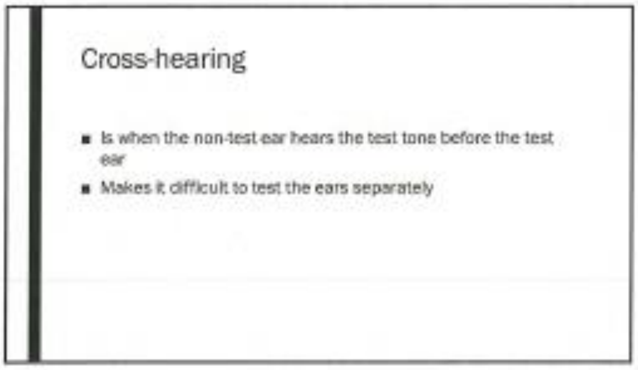
Interaural attenuation
is how much sound is **lost** as a sound travels from one ear to the other through the head
IA: 40dB
IA: 60dB
IA: 0dB



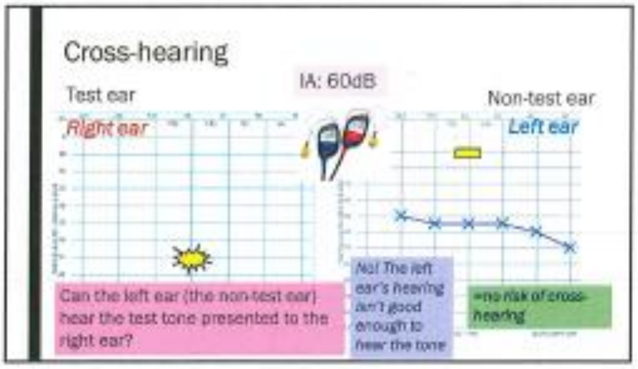
Interaural attenuation - example
IA: 40dB
Test ear
Non-test ear
65dB
25dB



Interaural attenuation - example
IA: 0dB
Non-test ear
Test ear
10dB
10dB

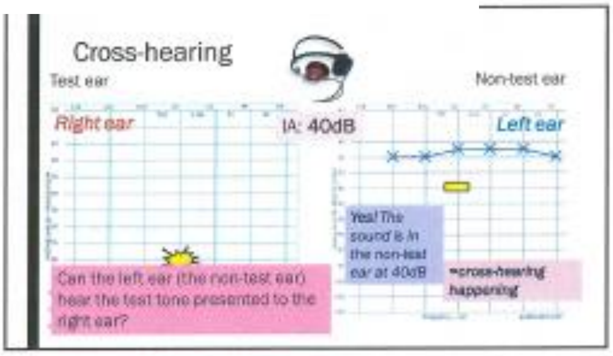


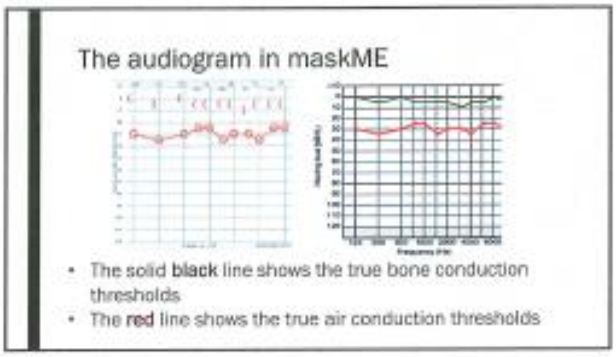
Cross-hearing
■ Is when the non-test ear hears the test tone before the test ear
■ Makes it difficult to test the ears separately

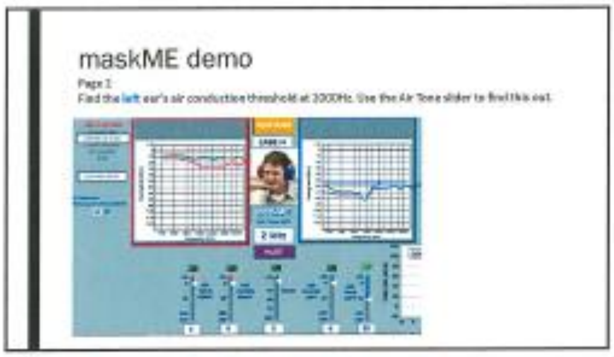


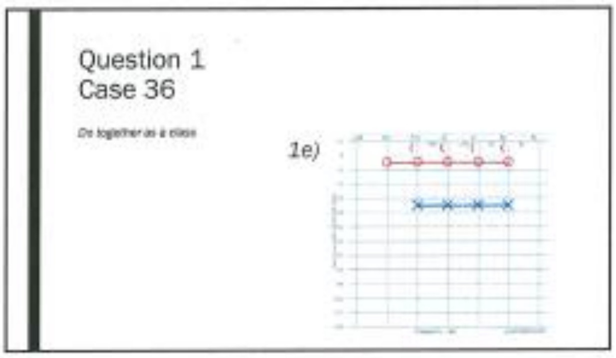
Cross-hearing
IA: 60dB
Test ear
Non-test ear
Right ear
Left ear
Can the left ear (the non-test ear) hear the test tone presented to the right ear?
No! The left ear's hearing isn't good enough to hear the tone
=no risk of cross-hearing

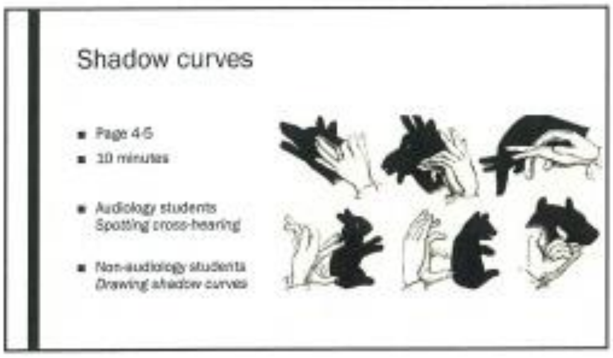
MASKING C

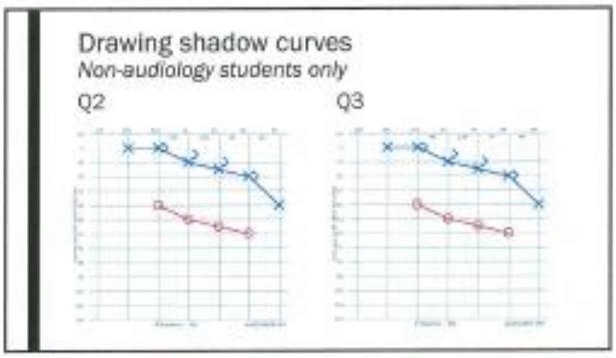

Cross-hearing
Test ear
Non-test ear
Right ear
IA: 40dB
Left ear
Yes! The sound is in the non-test ear at 40dB
=cross-hearing happening
Can the left ear (the non-test ear) hear the test tone presented to the right ear?


The audiogram in maskME
The solid black line shows the true bone conduction thresholds
The red line shows the true air conduction thresholds

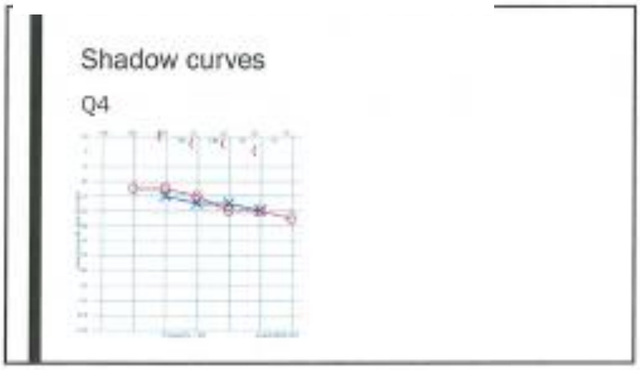

maskME demo
Page 1
Find the left ear's air conduction threshold at 2000Hz. Use the Air Tone slider to find this out.

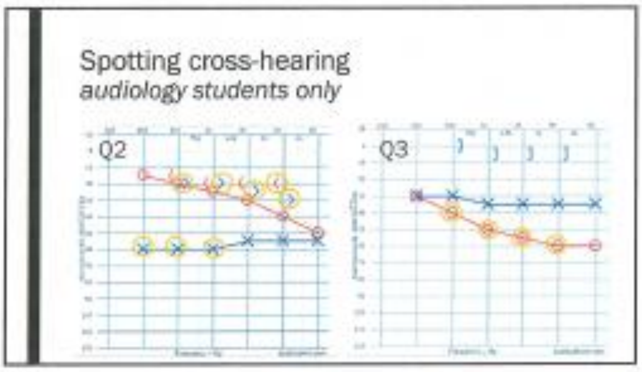

Question 1
Case 36
Do together as a class
1e)

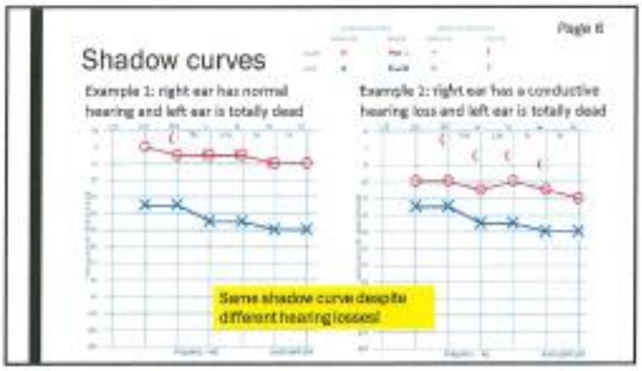

Shadow curves
Page 4-5
10 minutes
Audiology students
Spotting cross-hearing
Non-audiology students
Drawing shadow curves

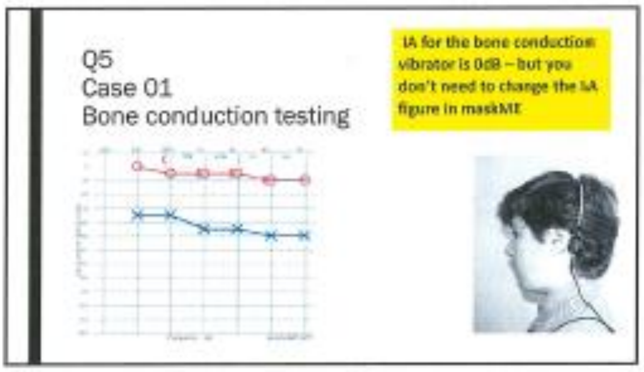

Drawing shadow curves
Non-audiology students only
Q2
Q3

MASKING C

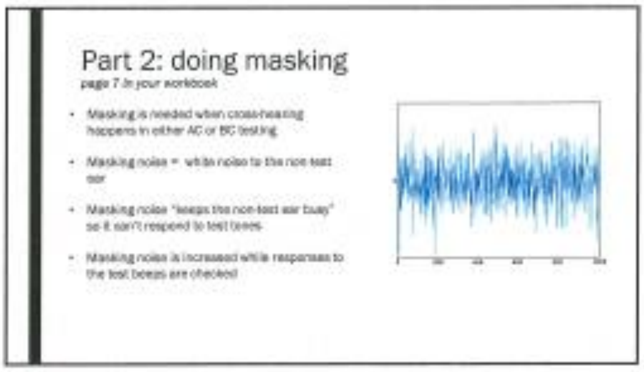

Shadow curves
Q4


Spotting cross-hearing
audiology students only
Q2
Q3

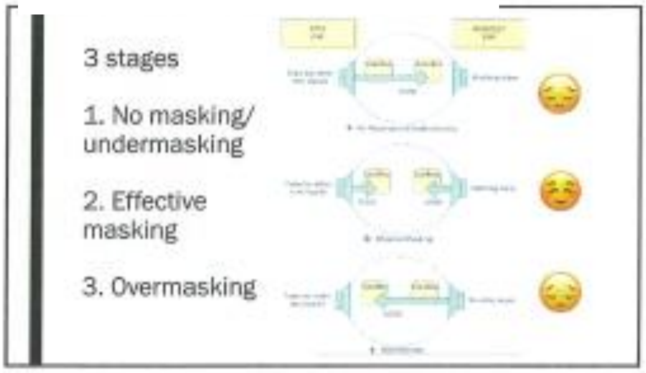

Page 6
Shadow curves
Example 1: right ear has normal hearing and left ear is totally dead
Example 2: right ear has a conductive hearing loss and left ear is totally dead
Same shadow curve despite different hearing losses!

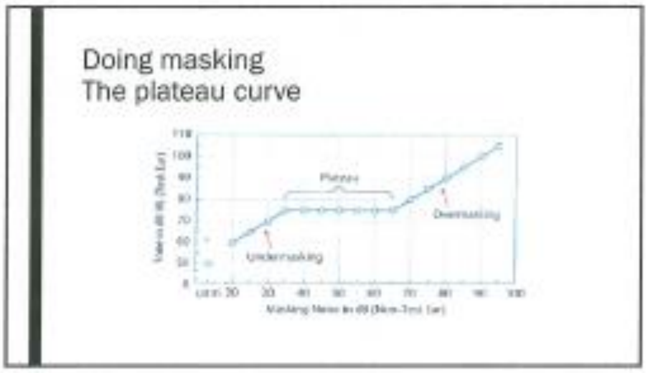

Q5
Case 01
Bone conduction testing
IA for the bone conduction vibrator is 0dB – but you don't need to change the IA figure in maskME

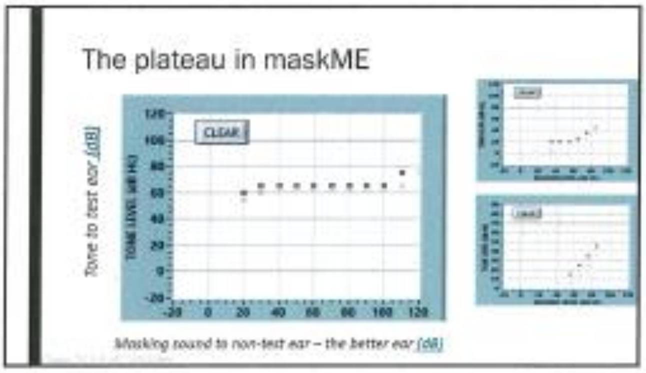

Break
TIME

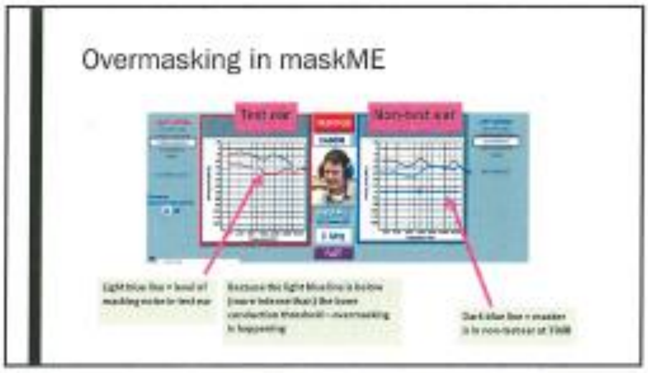

Part 2: doing masking
page 7 in your workbook
Masking is needed when cross-hearing happens in either AC or BC testing
Masking noise = white noise to the non-test ear
Masking noise "keeps the non-test ear busy" so it can't respond to test tones
Masking noise is increased while responses to the test beeps are checked

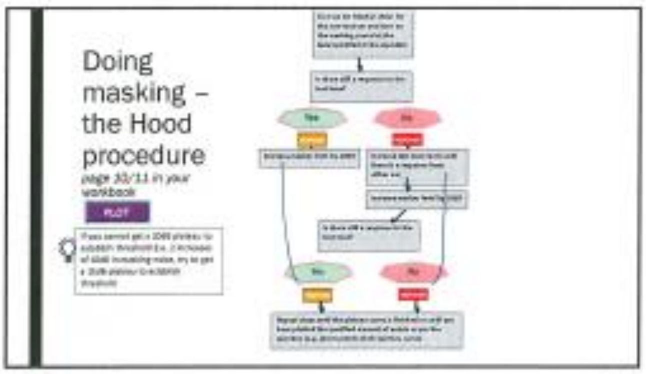
MASKING C


3 stages
1. No masking/ undermasking
2. Effective masking
3. Overmasking


Doing masking
The plateau curve
Plateau
Overmasking
Undermasking


The plateau in maskME
Tone to test ear (dB)
TONE LEVEL (dB HL)
CLEAR
Masking sound to non-test ear – the better ear (dB)

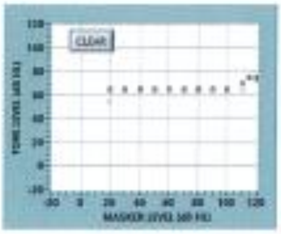

Overmasking in maskME
Test ear
Non-test ear


Doing masking – the Hood procedure
workbook
Yes
No


Doing masking
Workbook activities

MASKING C

Question 6 answer
Case 14



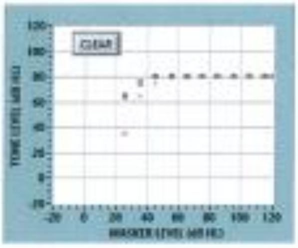
g) What is the left ear's true threshold at 2000Hz?

65dB

h) What happens after the plateau?

Overmasking starts

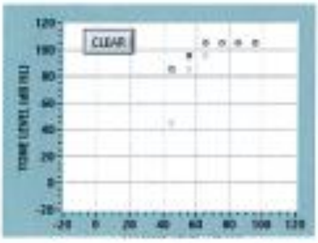
Question 7 answer
Case 01



g) What is the left ear's true threshold at 1000Hz?

80dB

Question 8
Case 02

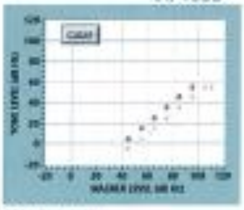


d) What is the left ear's true threshold at 1000Hz?

105dB

Question 9 - Case 19

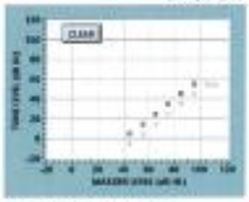
IA: 40dB



8b) No plateau

8c) Overmasking starts at 45dB - immediately

IA: 60dB

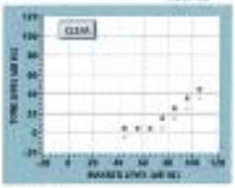


8e) 30dB plateau width

8f) Overmasking starts at 75dB of masking

Question 10 and 11 – Case 32 and 33

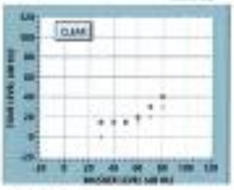
Case 32



9a) 5dB

9b) 30dB

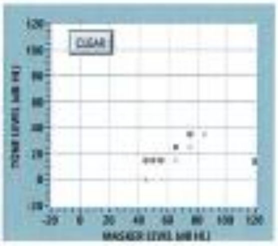
Case 33



10a) 15dB

10b) 10dB – not a plateau

Question 12 – Case 6

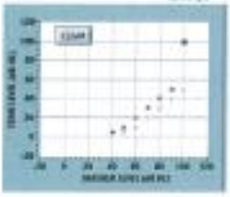


4. No - you can't get a plateau in this case!

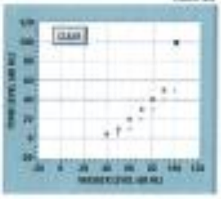
MASKING C

Question 13 and 14 – Case 15 and 13

Case 15



Case 13



13a) No – you can't get a plateau in this case!

14a) Yes, you can get a 15dB plateau.

Recap of concepts covered so far

- Intended learning outcomes

- Understand interaural attenuation
- Understand cross-hearing
- Understand shadow curves
- Understand the purpose of masking
- Understand the plateau
- Understand overmasking
- Understand how the following affect plateau width
  -interaural attenuation
  -the occlusion effect
  -the size of conductive components

The occlusion effect

<u>What is it?</u>

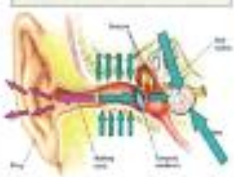
- An increase in low-frequency sounds when an ear/the ears are blocked.

<u>When does it happen in hearing testing?</u>

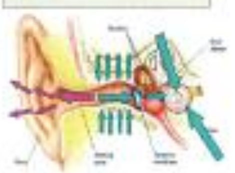
- When we need to mask the non-test ear during bone conduction – one ear is blocked.
- When we measure air-conduction thresholds – both ears are blocked.

The occlusion effect

Unoccluded – pink arrows show low frequency sounds escaping out of the ear canal



Occluded – pink arrows show low frequency sounds reflecting back into the cochlea



The occlusion effect

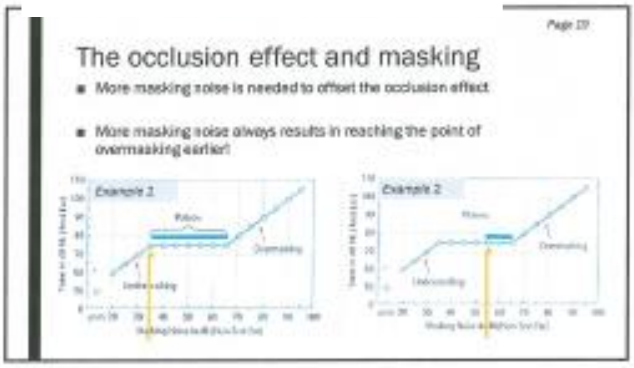
Is it a problem?

- Yes, for low-frequency bone-conduction testing
- Occluding the NTE increases the intensity of a bone-conducted signal
- →cross-hearing more likely

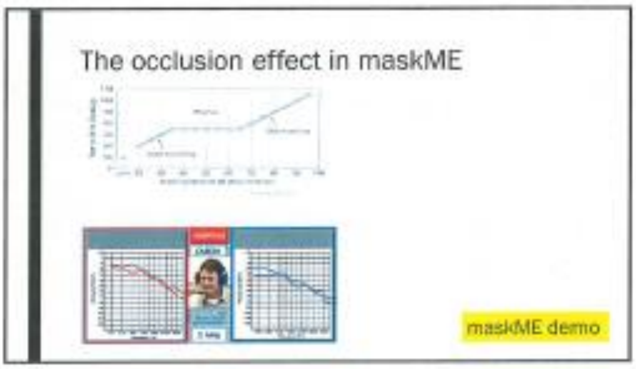
A

B

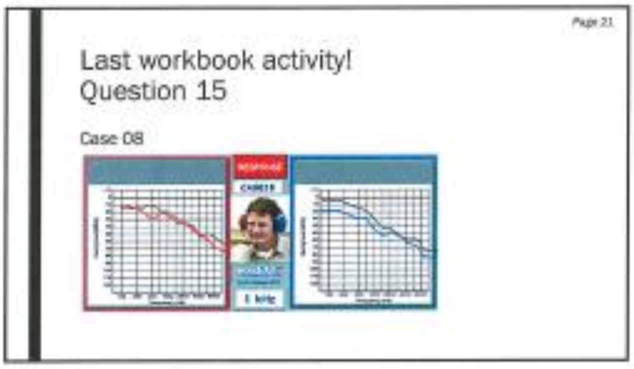
MASKING C



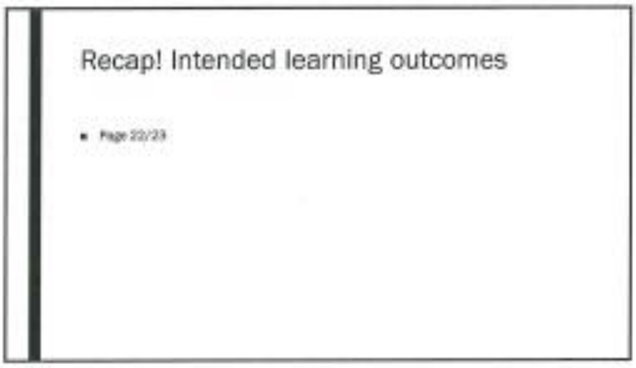
Page 19
The occlusion effect and masking
More masking noise is needed to offset the occlusion effect
More masking noise always results in reaching the point of overmasking earlier!
Example 1
Example 2



The occlusion effect in maskME
maskME demo



Page 21
Last workbook activity!
Question 15
Case 08

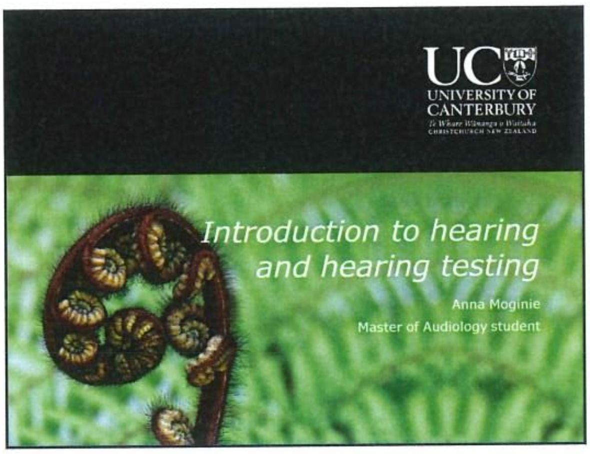


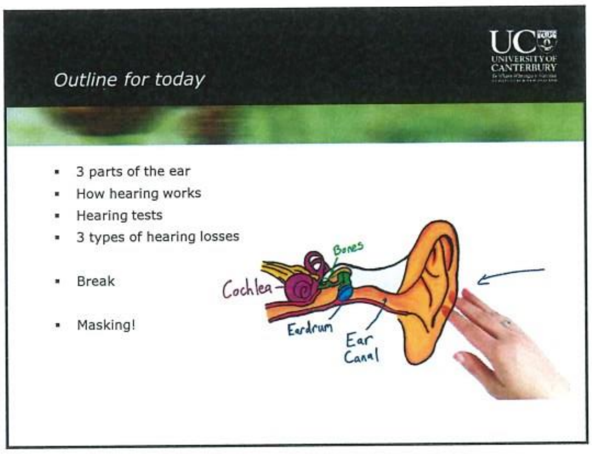
Recap! Intended learning outcomes
Page 22/23

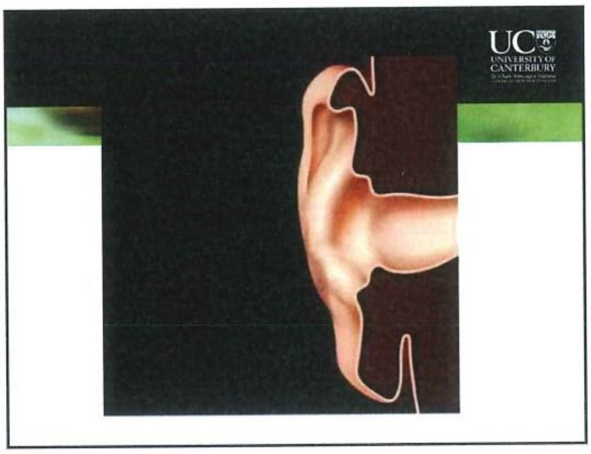
Kahoot quiz!
Enter game code

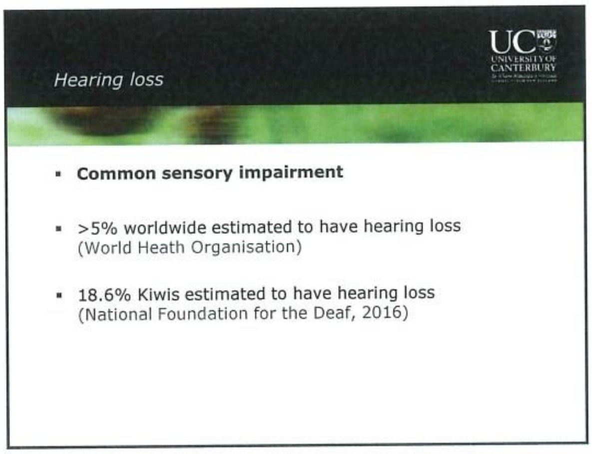
Quiz and questionnaire
Student ID on quiz only, please!
The questionnaire is anonymous
Please leave your workbooks on the desk
Collect your vouchers on your way out!
Thank you!

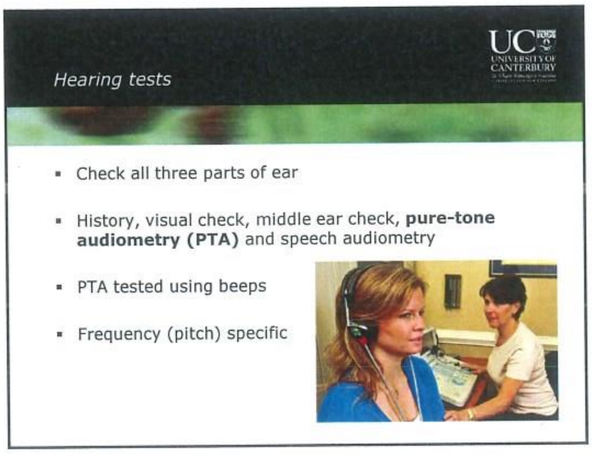
INTRODUCTION TO HEARING

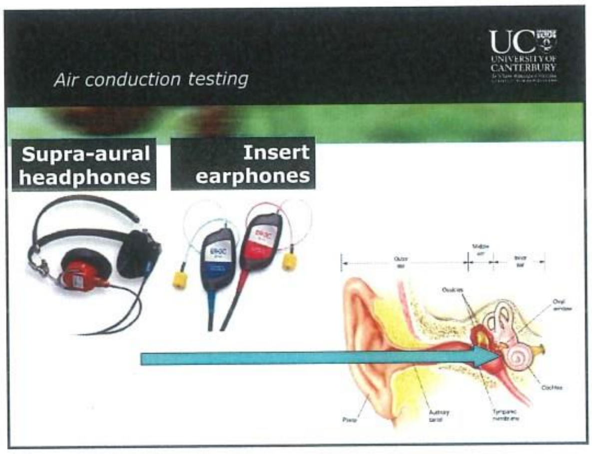




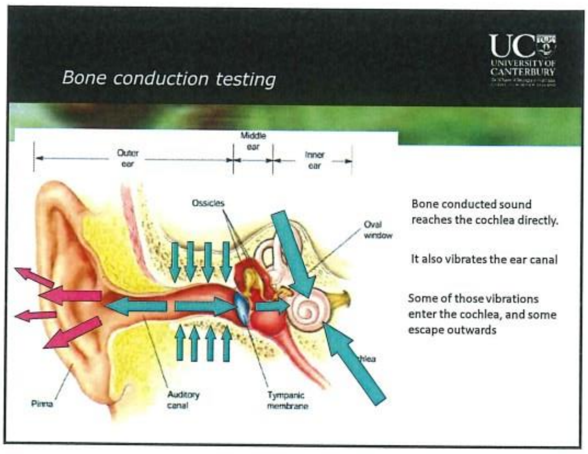


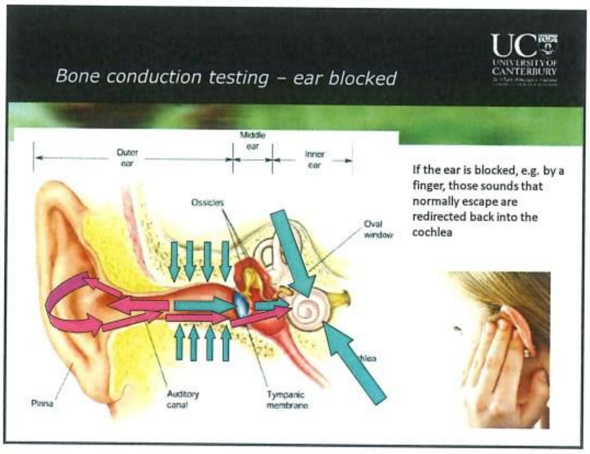


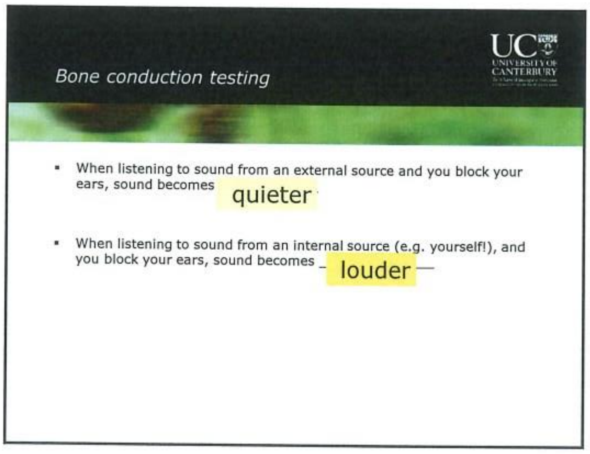


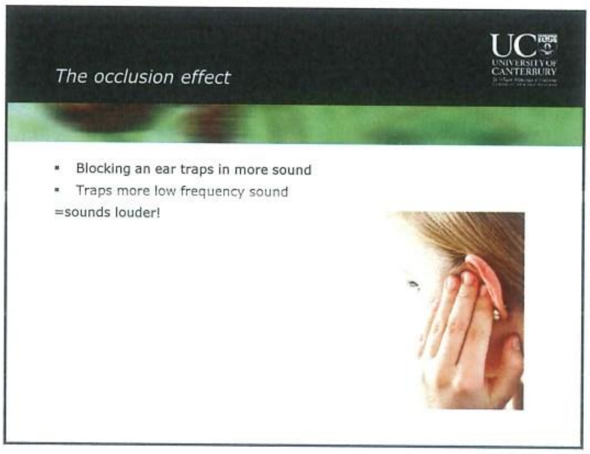


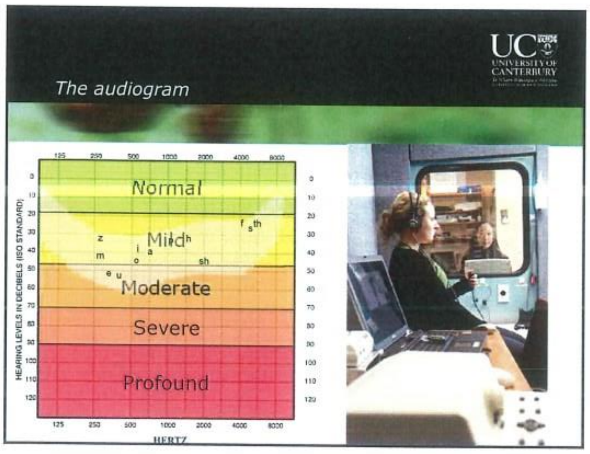
INTRODUCTION TO HEARING

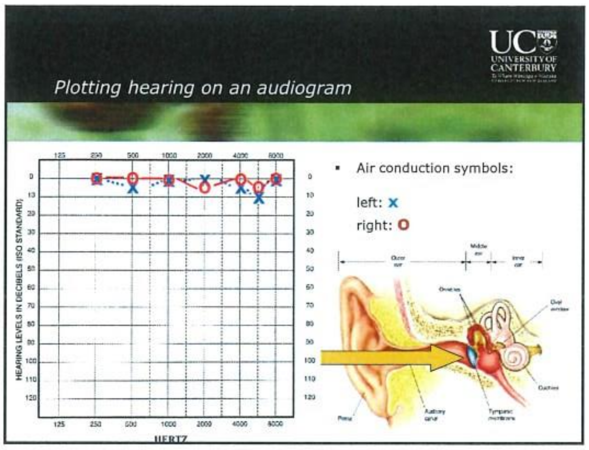


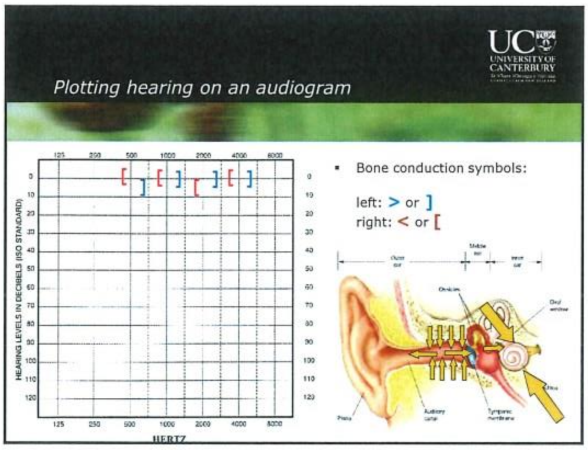


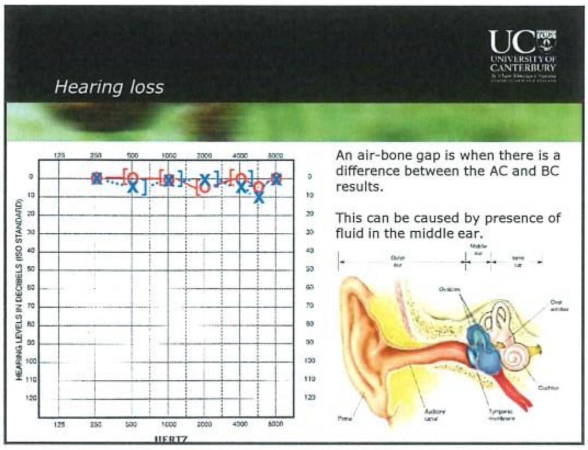


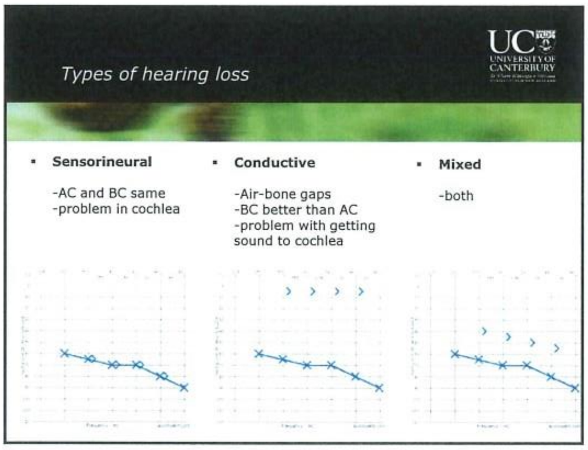


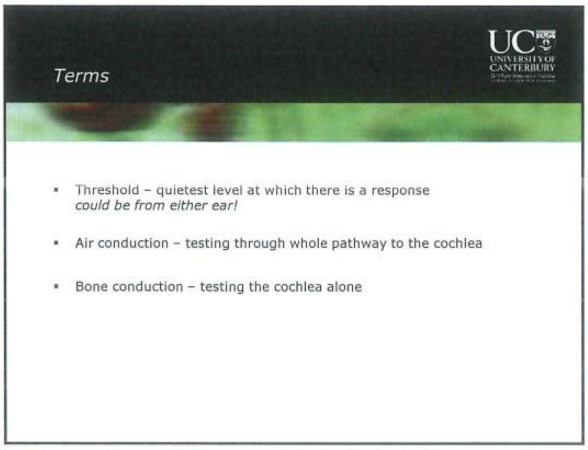


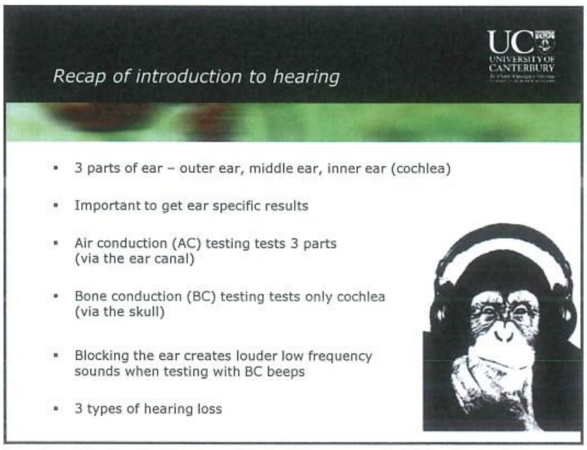

Plotting hearing on an audiogram
UC UNIVERSITY OF CANTERBURY
Air conduction symbols:
left: x
right: O
HEARING LEVELS IN DECIBELS (ISO STANDARD)
HERTZ


Plotting hearing on an audiogram
UC UNIVERSITY OF CANTERBURY
Bone conduction symbols:
left: > or]
right: < or [
HEARING LEVELS IN DECIBELS (ISO STANDARD)
HERTZ


Hearing loss
UC UNIVERSITY OF CANTERBURY
An air-bone gap is when there is a difference between the AC and BC results.
This can be caused by presence of fluid in the middle ear.
HEARING LEVELS IN DECIBELS (ISO STANDARD)
HERTZ


Types of hearing loss
UC UNIVERSITY OF CANTERBURY
Sensorineural
-AC and BC same
-problem in cochlea
Conductive
-Air-bone gaps
-BC better than AC
-problem with getting sound to cochlea
Mixed
-both


Terms
UC UNIVERSITY OF CANTERBURY
Threshold – quietest level at which there is a response
could be from either ear!
Air conduction – testing through whole pathway to the cochlea
Bone conduction – testing the cochlea alone


Recap of introduction to hearing
UC UNIVERSITY OF CANTERBURY
3 parts of ear – outer ear, middle ear, inner ear (cochlea)
Important to get ear specific results
Air conduction (AC) testing tests 3 parts (via the ear canal)
Bone conduction (BC) testing tests only cochlea (via the skull)
Blocking the ear creates louder low frequency sounds when testing with BC beeps
3 types of hearing loss

Appendix I: Multi-choice Kahoots Quizzes used in Session 4

I.1. Kahoots Quiz 1 after the *Introduction to Hearing* PowerPoint in Session 4.

A tick indicates the correct answer.

Q1: The colour for the right ear in audiology is		**Q9: These are the symbols for what threshold?**	
	Orange		Right ear air conduction
✓	Red		Left ear air conduction
	Blue	✓	Right ear bone conduction
	Green		Left ear bone conduction
Q2: The colour for the left ear in audiology is		**Q10: These are the symbols for what threshold?**	
✓	Blue	✓	Right ear air conduction
	Red		Left ear air conduction
	Green		Right ear bone conduction
	Orange		Left ear bone conduction
Q3: The inner ear is also known as the		**Q11: These are the symbols for what threshold?**	
	Circle		Right ear air conduction
	Air conduction	✓	Left ear air conduction
	Bone		Right ear bone conduction
✓	Cochlea		Left ear bone conduction
Q4: Air conduction testing tests		**Q12: These are the symbols for what threshold?**	
	The cochlea alone		Right ear air conduction
	The skull		Left ear air conduction
✓	How sound travels through the 3 parts of the ear		Right ear bone conduction
	The inner ear	✓	Left ear bone conduction
Q5: Air conduction testing uses		**Q13: An air bone gap means that**	
✓	Supra-aural headphones and insert earphones		Air conduction and bone conduction thresholds are the same
	Supra aural headphones		There's a gap in the skull
	Insert earphones	✓	Bone conduction results are better than air conduction ones
	The bone conduction vibrator		Some results are missing
Q6: Bone conduction testing tests		**Q14: A threshold is**	
✓	The cochlea alone		The cochlea
	The skull	✓	The quietest sound that can be heard
	How sound travels through the 3 parts of the ear		A small sound
	The middle ear alone		A low level sound
Q7: Bone conduction testing uses		**Q15: AC stands for**	
	Supra-aural headphones and insert earphones		Allo captain
	Supra aural headphones	✓	Air conduction
	Insert earphones		A chinchilla
✓	The bone conduction vibrator		Air caps
Q8: The occlusion effect makes which pitches louder in bone conduction testing?		**Q16: ABG stands for**	
	High pitches (frequencies)	✓	Air-bone gap
✓	Low pitches (frequencies)		Air-bone gorilla
			Air-bone grind
			Allo bone conductor
		Q17: BC stands for	
		✓	Bone conduction
			Bone captain
			Big conduction
			Bone conductor

I.2. Kahoots Quiz 2 after the *Masking C* PowerPoint in Session 4.

Q1: Supra-aural headphones have an interaural attenuation value of	
	0dB
	20dB
✓	40dB
	60dB
Q2: Air conduction testing	
	Tests the outer ear alone
	Tests the cochlea alone
	Tests the outer and middle ear only
✓	Tests how sound travels through all three parts of the ear
Q3: Interaural attenuation is	
	70dB
	The difference in thresholds between ears
	Cross-hearing
✓	Loss of sound energy through the skull between the cochleas
Q4: Bone conduction testing	
	Tests the middle ear only
	Tests the outer and middle ear only
✓	Tests the cochlea alone
	Tests all three parts of the ear
Q5: In hearing testing, a threshold is	
	The edge
	0dB
✓	The quietest sound heard
	A very quiet sound
Q6: In hearing testing, masking is done to	
✓	Get ear specific information
	Create the occlusion effect
	Increase cross hearing
	See how much ear eax there is

Q7: Cross hearing is	
	40dB
✓	When the test sound is audible in the non-test ear
	50dB
	When the test sound is present in the non-test ear
Q8: When an ear is blocked during masking, the _________ effect can happen!	
	conductive
✓	occlusion
	air-bone gap
	interaural attenuation
Q9: The occlusion effect improves ________ conduction thresholds	
	air
✓	bone
Q10: An air-bone gap is	
	due to cross-hearing
✓	a difference between air and bone conduction thresholds
	due to the occlusion effect
	40dB
Q11: A threshold needs to be masked when	
✓	Cross hearing happens
	Interaural attenuation is 40dB
	The person is lying
	You want to test 4000Hz

Appendix J: Quizzes

J.1. Quiz A used in Session

Student ID number ___________________________
Your ID number will not be shared with academic staff

Masking quiz A

OK to use the following abbreviations: RE – right ear LE – left ear AC – air conduction BC – bone conduction	OE – occlusion effect ABG – air-bone gap HL – hearing loss SNHL – sensorineural hearing loss CHL – conductive hearing loss IA: interaural attenuation

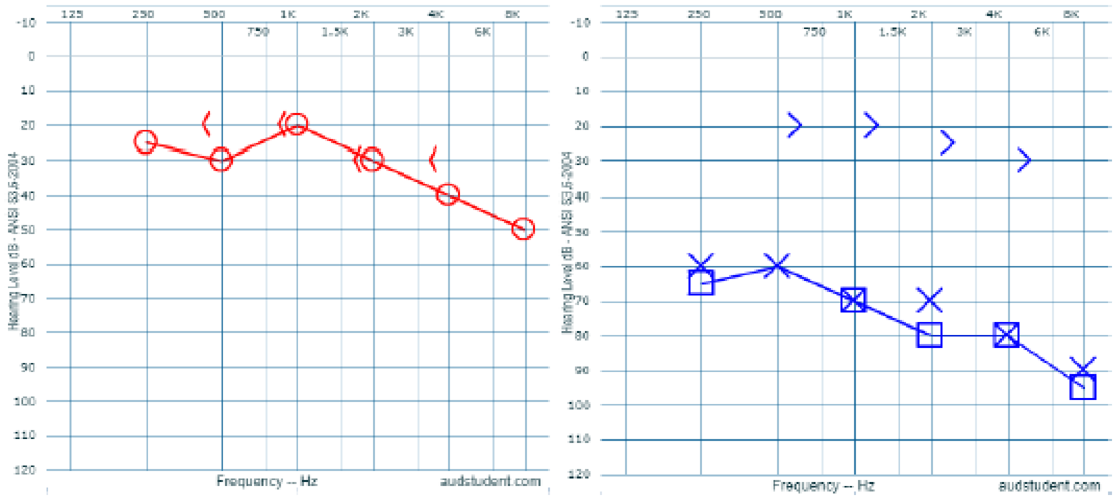
1. Why is masking done in hearing tests?
2. Define interaural attenuation
3. What does it mean if a plateau cannot be obtained?
4. When do air conduction thresholds not need masking?
5. What is overmasking and why is problematic in testing?
6. Is cross-hearing more or less likely with a large interaural attenuation? (e.g. large being 75dB, small being 0dB)
7. Explain why a significant air-bone gap must be corrected for during speech masking
8. In air conducting testing, both ears are occluded. Why do we *not* need to consider the occlusion effect when testing with air-conduction stimuli, or when masking air-conduction thresholds?
9. Why do we need to add extra masking noise to compensate for the occlusion effect?
10. Does the occlusion effect affect both ears when the masking transducer is only occluding one ear? Why or why not?
11. Describe two types of hearing losses that lead to masking dilemmas
12. How do the following factors affect plateau width?
    a. The occlusion effect
    b. Absolute hearing threshold in the test ear
    c. Conductive component (i.e. air bone gap)
    d. Interaural attenuation
13. How are the standard Hood and the step masking procedures different?

J.1. Quiz A used in Sesion 1

	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	⌶ or □	>	]

Case based questions

Case A



Open boxes are left ear masked air conduction thresholds

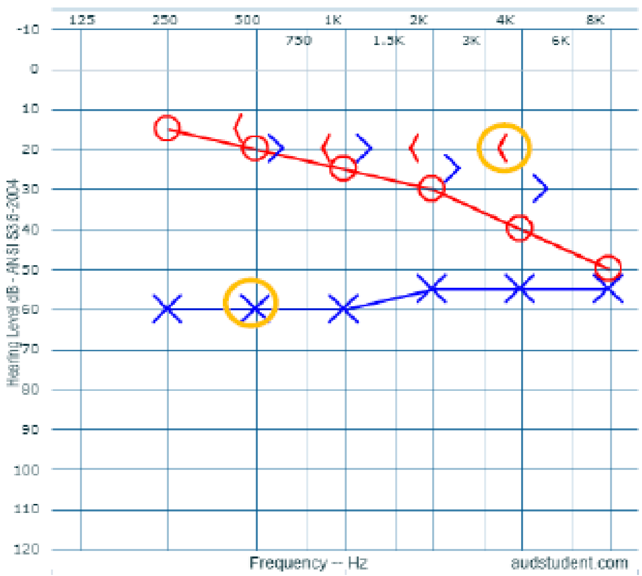
Should the left AC 500Hz threshold have been masked? Why/why not?

Should the left AC 1000Hz have been masked? Why/why not? (

	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	⌶ or □	>	]

Case B

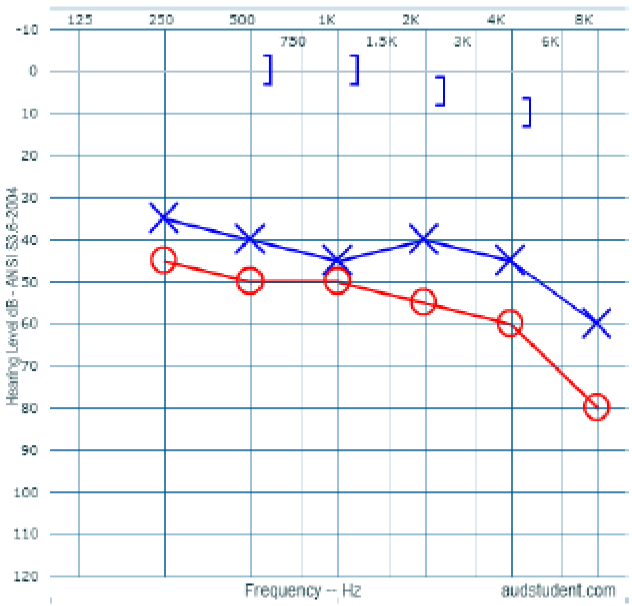
Circle any threshold that should be masked if you got these results using supra-aural headphones (interaural attenuation: 40dB) and the bone conduction vibrator (interaural attenuation: 0dB). The first two have been done for you.



J.1. Quiz A used in Sesion 1

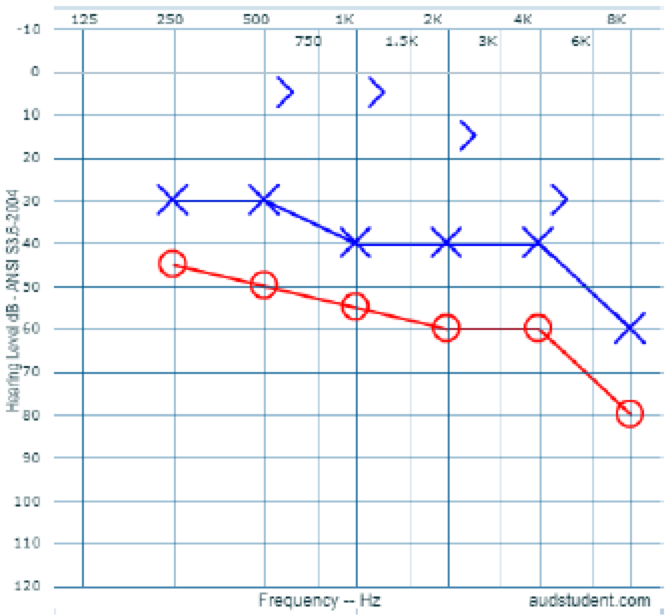
Case C

Circle any threshold that should be masked if you got these results using supra-aural headphones (interaural attenuation: 40dB for all frequencies) and the bone conduction vibrator (interaural attenuation: 0dB)



Would you attempt to get masked bone conduction thresholds in this client? Why or why not?

Case D: speech masking



Speech stimuli are presented to the right ear at 65dB using insert earphones (interaural attenuation: 50dB). Would you need to mask the left ear? Why or why not?

End of quiz

J.2. Quiz A marking schedule

Marking schedule for Quiz A				
	Quiz A			
	Used in Group 1 - 2nd year audiology students			
	Question	**Answer**	**Points**	**Notes**
1	Why is masking done in hearing tests?	To get ear specific information	1	
2	Define interaural attenuation	Amount of sound energy lost as it travels from one cochlea to the other	1	
3	What does it mean if a plateau cannot be obtained?	Ear specific information cannot be obtained	1	
4	When do air conduction thresholds not need masking?	When there is no indication that cross-hearing is happening	1	
5	What is overmasking and why is problematic in testing?	When the masking sound is audible in the test ear. It is problematic because it raises the threshold of the test ear / cannot get accurate threshold information from the test ear	2	
6	Is cross-hearing more or less likely with a large interaural attenuation? (e.g. large being 75dB, small being 0dB)	Less	1	
7	Explain why a significant air-bone gap must be corrected for during speech masking	Masking sound must be able to overcome the condutive component and reach the cochlea at the desired level	2	
8	In air conducting testing, both ears are occluded. Why do we not need to consider the occlusion effect when testing with air-conduction stimuli, or when masking air-conduction thresholds?	Not comparing between unoccluded and occluded conditions and the occlusion effect for air conduction testing is built into the audiometer	2	
9	Why do we need to add extra masking noise to compensate for the occlusion effect?	*This question removed from the marking schedule because it was not taught in the session*	*0*	*This question removed from the marking schedule because it was not taught in the session*
10	*Does the occlusion effect affect both ears when the masking transducer is only occluding one ear? Why or why not?*	*This question removed from the marking schedule because it was not taught in the session*	*0*	*This question removed from the marking schedule because it was not taught in the session*
11	Describe two types of hearing losses that lead to masking dilemmas	Bilateral mild-moderate conductive hearing loss, one ear with a slight-moderate conductive hearing loss, large asymmetrical hearing loss	2	1 point for each correct answer
12	How do the following factors affect plateau width?			
a	The occlusion effect	The larger the occlusion effect, the shorter the plateau	1	
b	Absolute hearing threshold in the test ear	This does not affect plateau width unless the threshold is very high (i.e. poor), in which case masking noise may be limited by the audiometer	1	
c	Conductive component (i.e. air bone gap)	The larger the conductive component, the shorter the plateau	1	
d	Interaural attenuation	The larger the interaural attenuation, the wider/larger the plateau	1	
13	How are the standard Hood and the step masking procedures different?	Hood uses smaller step sizes than Step. Hood is more conservative	2	
Case A	Should the left AC 500Hz threshold have been masked? Why/why not?	Yes, because of the cross-hearing risk due to the bone conduction threshold in the right ear	2	1 point for 'yes', second point for explanation why
	Should the left AC 1000Hz have been masked? Why/why not? (	Yes, because of the cross-hearing risk due to the bone conduction threshold in the right ear	2	1 point for 'yes', second point for explanation why
	What is likely generating the unmasked bone conduction results for the left ear?	The right cochlea	1	
Case B	Circle thresholds that should have been masked		6	1 point for every correctly circled threshold
Case C	Circle thresholds that should have been masked		4	1 point for every correctly circled threshold
	Would you attempt to get masked bone conduction thresholds in this client? Why or why not?	Yes, even though you would likely run into overmasking	2	1 point for 'yes', second point for recognising that overmasking may happen
Case D	Speech stimuli are presented to the right ear at 65dB using insert earphones (interaural attenuation: 50dB). Would you need to mask the left ear? Why or why not?	Yes because the bone conduction thresholds in the non-test ear are below the level of crossover	2	1 point for 'yes', extra point for why
	Total marks possible		***38***	

J.3. Quiz B used in Session 2

Student ID number ____________________________
Your ID number will not be shared with academic staff

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Masking quiz B - 20 minutes

OK to use the following abbreviations: RE – right ear LE – left ear AC – air conduction BC – bone conduction	OE – occlusion effect ABG – air-bone gap HL – hearing loss SNHL – sensorineural hearing loss CHL – conductive hearing loss IA: interaural attenuation

---

1. Define interaural attenuation
2. Why do we aim to get a plateau during masking?
3. What is overmasking and why is problematic in testing?
4. For low frequency sounds (1000Hz and under) in masked bone conduction threshold testing, more masking noise is required to compensate for the OE. Why is more masking noise needed?
5. Does the occlusion effect affect both ears when the masking transducer is only occluding one ear? Why or why not?
6. In air conducting testing, both ears are occluded. Why do we *not* need to consider the occlusion effect when testing with air-conduction stimuli, or when masking air-conduction thresholds?
7. Plateau width (between under and over masking) can be affected by several factors. Circle the correct answers
   a) The larger the interaural attenuation, the **shorter/longer/same** the plateau.

   b) The larger the conductive component, the **shorter/longer/same** the plateau

   c) The larger the occlusion effect, the **shorter/longer/same** the plateau

J.3. Quiz B used in Session 2

	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	⧗ or □	>	]

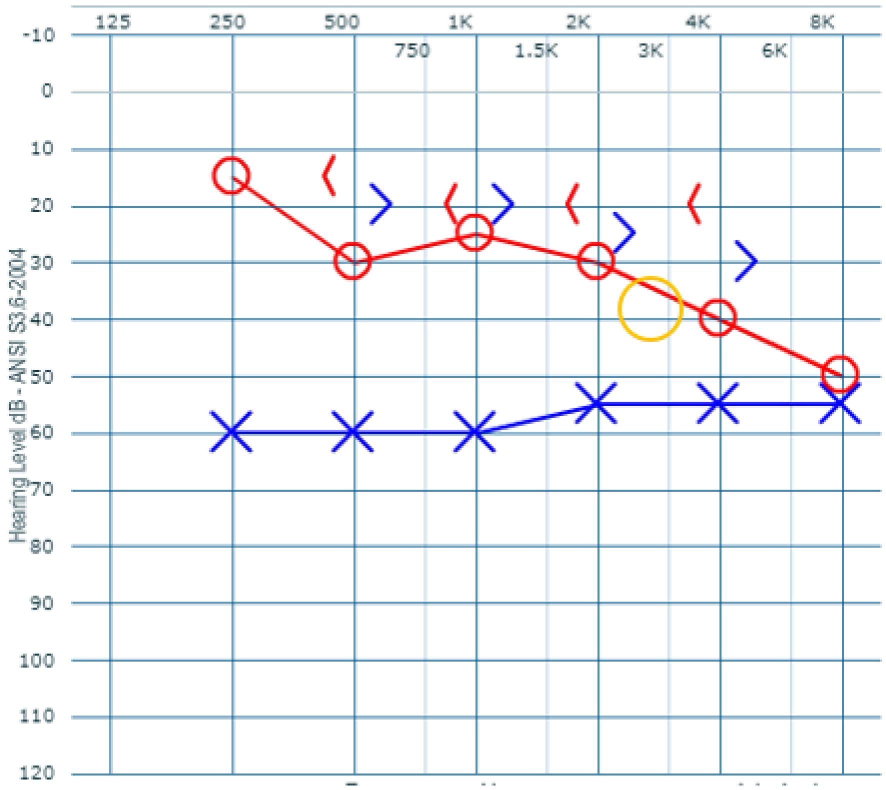
Case based questions

Case A

Circle any threshold that should be masked if you got these results. The first one has been done for you. **Both** bone conduction and air conduction thresholds may need to be masked.

Supra-aural headphones were used (interaural attenuation: 40dB)

The bone conduction vibrator has an interaural attenuation of 0dB.



J.3. Quiz B used in Session 2

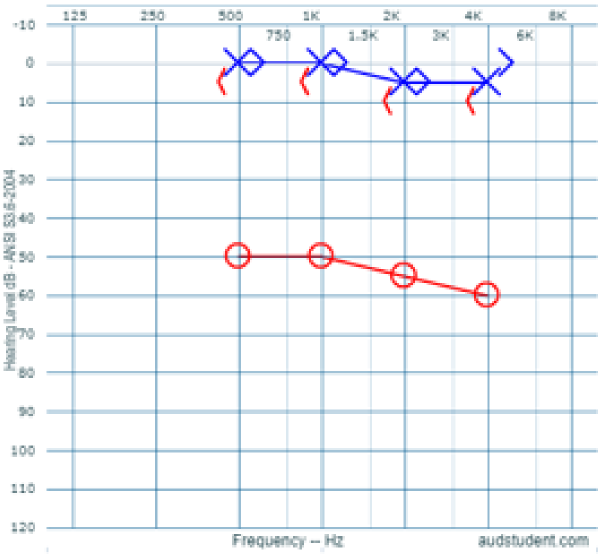
Case based questions

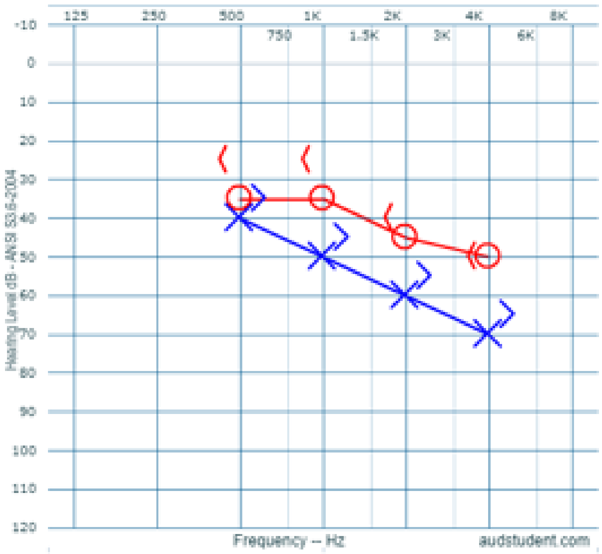
Case B

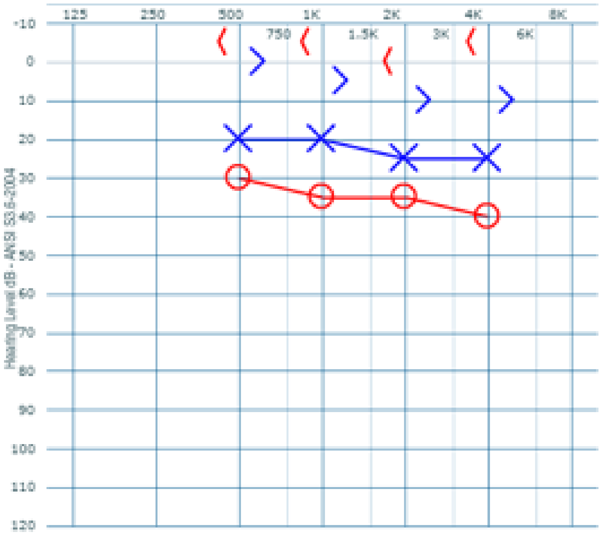
	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	⧗ or □	>	]

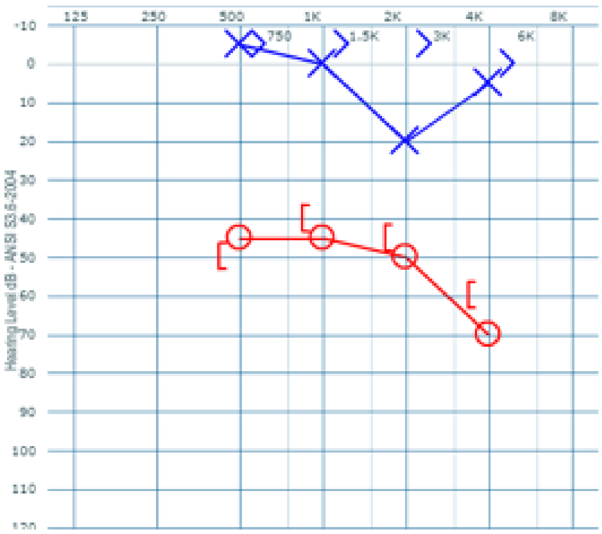
Circle the audiograms which have configurations which could lead to a masking dilemma. Circle the whole audiogram, not just one threshold.

Transducer: supra-aural headphones with 40dB interaural attenuation.









End of quiz

J.4. Quiz B marking schedule

Marking schedule for Quiz B				
	Quiz B			
	Used for Group 2, year 1 audiology students			
	Question	**Answer**	**Points**	**Notes**
1	Define interaural attenuation	Amount of sound energy lost as it travels from one cochlea to the other	1	
2	Why do we aim to get a plateau during masking?	To ensure we are getting ear specific information / to ensure the non-test ear is not responding to the test tone / to ensure responses are from the test ear	1	
3	What is overmasking and why is problematic in testing?	When the masking sound is audible in the test ear. It is problematic because it raises the threshold of the test ear / cannot get accurate threshold information from the test ear	2	1 point for each part of the question answered correctly
4	For low frequency sounds (1000Hz and under) in masked bone conduction threshold testing, more masking noise is required to compensate for the OE. Why is more masking noise needed?	*This question removed from the marking schedule because it was not taught in the session*	0	*This question removed from the marking schedule because it was not taught in the session*
5	Does the occlusion effect affect both ears when the masking transducer is only occluding one ear? Why or why not?	*This question removed from the marking schedule because it was not taught in the session*	0	*This question removed from the marking schedule because it was not taught in the session*
6	In air conducting testing, both ears are occluded. Why do we not need to consider the occlusion effect when testing with air-conduction stimuli, or when masking air-conduction thresholds?	Not comparing between unoccluded and occluded conditions and the occlusion effect for air conduction testing is built into the audiometer	2	1 point for each part of the question answered correctly
7	Plateau width (between under and over masking) can be affected by several factors. Circle the correct answers			
a	The larger the interaural attenuation, the shorter/longer/same the plateau.	Longer	1	
b	The larger the conductive component, the shorter/longer/same the plateau	Shorter	1	
c	The larger the occlusion effect, the shorter/longer/same the plateau	Shorter	1	
8	Circle thresholds that need to be masked		8	8 to find, 1 point per correctly circled threshold
9	Circle audiograms that could lead to a masking dilemma		3	3 correct answers, 1 point per correctly circled answer
	Total marks possible		***20***	

J.5. Quiz C used in Sessions 3 and 4

Student ID number ___________________________

Your ID number will not be shared with academic staff

Masking quiz C - 20 minutes

---

1. Define interaural attenuation
2. What is cross-hearing?
3. Which cochlea (test ear or non-test ear) is responding to the test signal during the plateau?
4. What is overmasking?
5. Why is overmasking problematic in testing?
6. Imagine you're testing bone conduction thresholds and that you have occluded the non-test ear with a headphone because you are masking.

a) When presenting low-frequency sounds (1000Hz and under), do you need *less* or *more* masking noise?

b) Why?

7. The plateau width is shorter (i.e. overmasking happens sooner) when:
   Circle the correct answer for each situation
   a) Interaural attenuation is **smaller** (e.g. 0dB) or **larger** (e.g. 50dB)
   b) Conductive components (air-bone gaps) are **smaller** (e.g. 0dB) or **larger** (e.g. 30dB)
   c) The occlusion effect in bone conduction testing is **present** (i.e. with frequencies under 1000Hz) or **absent**.

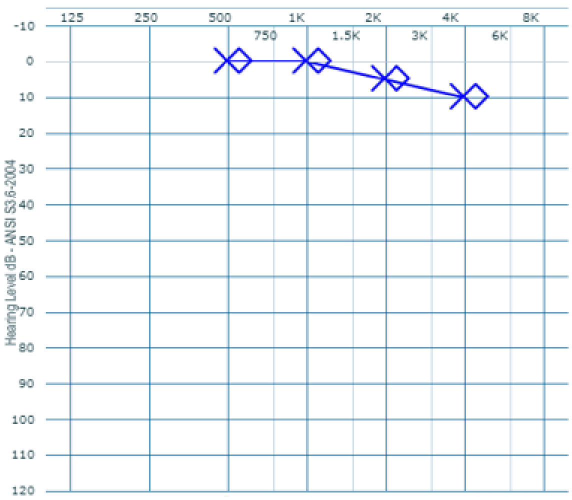
J.5. Quiz C used in Sessions 3 and 4

Shadow curves

	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	⧗ or □	>	]

1. Imagine that the right ear is totally dead. Draw the shadow curve you would get if you were testing the right ear's air conduction thresholds. Mark them with open circles.

   Imagine you have used supra-aural headphones which have an interaural attenuation value of 40dB.

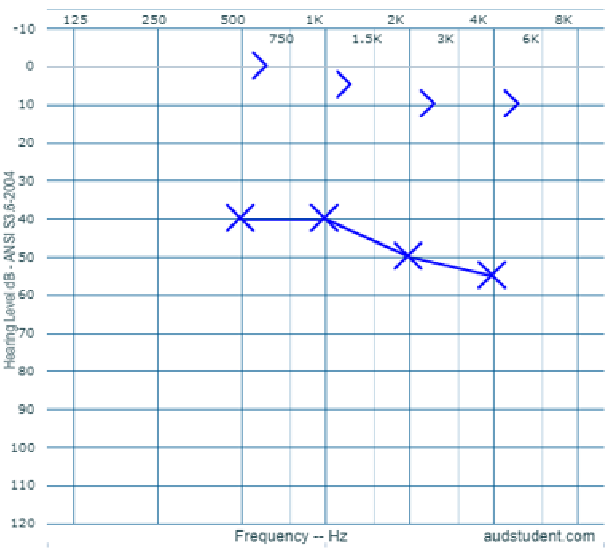


Shadow curves

	AIR CONDUCTION		BONE CONDUCTION	
	UNMASKED	MASKED	UNMASKED	MASKED
RIGHT	O	● or △	<	[
LEFT	X	⧗ or □	>	]

2. Imagine that the right ear is totally dead. Draw the shadow curve you would get if you were testing the right ear's air conduction thresholds. Mark them with open circles.

Imagine you have used insert earphones which have an interaural attenuation value of 60dB.



End of quiz

J.6. Quiz C marking schedule

Marking schedule for Quiz C				
	Quiz C			
	Used in Groups 3, 4, 5 and 6			
Question number	**Question**	**Answer**	**Points**	**Notes**
1	Define interaural attenuation	Amount of sound energy lost as it travels from one cochlea to the other	1	
2	What is cross-hearing?	When the non-test ear hears the test stimuli before the test ear	1	
3	Which cochlea (test ear or non-test ear) is responding to the test signal during the plateau?	Test ear	1	
4	What is overmasking?	When the masking sound is audible in the test ear	1	
5	Why is overmasking problematic in testing?	It raises the threshold of the test ear / cannot get accurate threshold information from the test ear	1	
6	*Imagine you're testing bone conduction thresholds and that you have occluded the non-test ear with a headphone because you are masking.*			
	a) When presenting low-frequency sounds (1000Hz and under), do you need less or more masking noise?	More	1	
	b) Why?	To compensate for the occlusion effect	1	
7	*The plateau width is shorter (i.e. overmasking happens sooner) when:*			
	a) Interaural attenuation is smaller (e.g. 0dB) or larger (e.g. 50dB)	Smaller	1	
	b) Conductive components (air-bone gaps) are smaller (e.g. 0dB) or larger (e.g. 30dB)	Larger	1	
	c) The occlusion effect in bone conduction testing is present (i.e. with frequencies under 1000Hz) or absent.	Present	1	
8	Draw a shadow curve 1 (IA: 40dB and SNHL)		1	1 point if all 4 marks are correct
9	Draw a shadow curve 2 (IA: 60dB and CHL)		1	1 point if all 4 marks are correct
	Total marks possible		***12***	

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Appendix K: Questionnaires

K.1. Questionnaire A

End of session questionnaire - anonymous

Please be honest! Your feedback will help us improve the way masking is taught to first year audiology students.

<u>The session</u>

The session was well organised.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?______________________________

The tutor was able to communicate ideas and information clearly.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?______________________________

My ability to confidently recognise situations that need to be masked improved after the session

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?______________________________

I think the session was useful for learning about cross-hearing

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?______________________________

I think the session was useful for learning about the occlusion effect

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

I think the session was useful for learning about the plateau

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

Please turn over!

K.1. Questionnaire A

I found maskME easy to use

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

I would recommend the session as a tool for first-year audiology students

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

<u>Open feedback about any aspects of today's session</u>

List any positive aspects from today

What would you like to see changed in the session?

Anything else you think we should know about the session?

K.2. Questionnaire B

End of session questionnaire - anonymous

Please be honest! Your feedback will help us improve the way masking is taught to first year audiology students.

Demographic information

Age _____________

Are you currently a student? yes/no

If so, what degree are you studying towards?

____

Years of post-high school education ________________

Highest level of education currently achieved:

NCEA level 3 / Bachelors / Honours / Masters / Doctorate / other:

____

The session

The session was well organised.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

The tutor was able to communicate ideas and information clearly.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

My ability to confidently recognise situations that need to be masked improved after the session

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

I think the session was useful for learning about cross-hearing

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

Please turn over!

K.2. Questionnaire B

I think the session was useful for learning about the occlusion effect

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

I think the session was useful for learning about the plateau

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

I found maskME easy to use

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

I would recommend the session as a tool for first-year audiology students

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

<u>Open feedback about any aspects of today's session</u>

List any positive aspects from today

What would you like to see changed in the session?

Anything else you think we should know about the session?

K.3. Questionnaire C

End of session questionnaire - anonymous

Please be honest! Your feedback will help us improve the way masking is taught to first year audiology students.

Demographic information

Age _____________

Are you currently a student? yes/no

If so, what degree are you studying towards? e.g. Bachelors of Science majoring in Marine Biology

____

Years of post-high school education ________________

Highest level of education currently achieved:

NCEA level 3 / Bachelors / Honours / Masters / Doctorate / other:

____

The session

The session was well organised.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Any other comments?____

The tutor was able to communicate ideas and information clearly.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Any other comments?____

My ability to confidently recognise situations that need to be masked improved after the session

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Any other comments?____

I think the session was useful for learning about cross-hearing

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Any other comments?____

Please turn over!

K.3. Questionnaire C

I think the session was useful for learning about the occlusion effect

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Any other comments?____

I think the session was useful for learning about the plateau

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Any other comments?____

I found maskME easy to use

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Any other comments?____

I would recommend the session as a tool for first-year audiology students

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Any other comments?____

If you are an audiology student who attended the first masking session:

Since the session (17 August for second year students and 27 August for first year students),

approximately how many masked audiograms have you done? _________________

To what extent do you think the masking session helped you with those masked audiograms?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Any other comments?____

K.3. Questionnaire C

<u>Open feedback about any aspects of today's session</u>

List any positive aspects from today

What would you like to see changed in the session?

Anything else you think we should know about the session?

Appendix L: Full transcripts of the open ended feedback from the questionnaires by session

L.1. Session 1 transcript of questionnaire feedback

List any positive aspects from today

- Anna explained the basic of masking clearly
- The tool visually shows cross-over making it easy to see when there is likely to be cross-hearing or overmasking
- Good refresher
- Learnt more about some things so feel like I understand most concepts better
- Helped me think about why we need masking/be rigorous in clinic more
- Good learning and teaching style
- Display of information on the workbook was effective
- Language was really accessible
- Refreshed my memory on masking concepts and made me realise what I need to revise
- Anna explained things in a very clear manner and was super helpful!!
- Good, clear information presented
- Anna is awesome
- Outlines theory of masking that we do but don’t fully understand why or how it works – very helpful!
- Easy to follow workbook and session
- Explanation of concepts
- On hand help with software

What would you like to see changed in the session?

- A little more time
- The tool was quite confusing to use
- I think it would be great if the presentation levels were shown directly on the audiogram rather than on the sliders because it’s difficult to follow with so much on the screen and having it on the audiogram would force users to look at the visual representation that I think would be useful – but I found I ignored it because it is so busy
- Would have liked to finish all the examples in booklet as were good practice
- More time
- How does this apply to what we do at UC?
- More time for testing and practising is probably the only thing I can think of!
- Less exercises to do – ran out of time
- Need more time
- maskME could look more visually appealing and be easier to use (easier if we could use the keyboard instead of mouse)

L.1. Session 1 transcript of questionnaire feedback

Anything else you think we should know about the session?

- It was rad
- Nah. Good session!
- I think it's super helpful and would love to get the workbook/software to practise!

Extra comments on the Likert scale statements

The session was well organised

- Nice flow. A little more time would have been good.
- Very well organised but more time would have been great

My ability to confidently recognise situations that need to be masked improved after the session

- It was a refresher but I think I already knew what I know now (circled disagree)
- Do our masking rules still apply though?
- Would love to practise more with software and workbook!
- Found programme hard to orient to – hard to say after only one session (rated neutral)

I think the session was useful for learning about cross-hearing

- I now understand the link between IA and cross-hearing

I think the session was useful for learning about the occlusion effect

- Still not 100% sure about the 2 ears occluded…

I think the session was useful for learning about the plateau

- Really great to have the visual!

I found maskME easy to use

- Took some time but once got heard around it, it was fine!
- Annoying that you had to click the green button to turn on noise – should happen as you use slider

I would recommend the session as a tool for first-year audiology students

- Would be so helpful!
- Lack of patient response feedback, i.e. compared to Parrot was not as easy (circled disagree)

L.2. Session 2 transcript of questionnaire feedback

List any positive aspects from today

- Good handouts with clear explanations
- Range of ideas covered during the session
- Easy to follow
- Concepts well explained
- I understood why masking plateau works – I struggled with the concept before
- Good support with the concepts
- Class interaction
- Lots of case examples
- Good organisation
- Snacks ☺ and break
- Didn't feel rushed
- Going over things as a class helped
- Background info on reasoning behind methods was useful
- Helped provide some understanding that I was lacking before
- maskME was easy to use and understand
- Cases were helpful in assisting my learning
- Plateau was helpful and easy to understand
- Great work Anna!! Was super helpful ☺
- Anna was very friendly and approachable
- Anna was super helpful
- I understand masking better because Anna made it easy to understand
- Aspects such as overmasking is easier to understand now

What would you like to see changed in the session?

- Nothing! Apart from maybe having more time ☺
- We need more time for the session – it felt rushed and we skipped a lot of concepts that I was just about to understand. Maybe a PowerPoint would be helpful to explain than just showing on maskME.
- Maybe more instructions on how to do the masking steps/plots in maskME?
- maskME slider controls – make them a bit clearer and space between steps bigger or different way of controlling levels
- Maybe some on speech masking
- More on the occlusion effect
- Description of what terms are, e.g. shadow effect and why it is important or what it suggests
- Nothing

Anything else you think we should know about the session?

- Main/only concern is with the software and how fiddly it is to change presentation level

L.2. Session 2 transcript of questionnaire feedback

- I just think the session needs to be longer to flesh out the concepts and not rush parts. Also, I felt we were tired after the manufacturers' day. Thanks for your time and good luck for your thesis Anna! ☺
- Still got confused during the test, but likely a personal fault rather than that of the session
- Going through steps of how you would test in clinic is helpful and how the equations are associate and why do we add OE. The LF OE was not explained therefore I put the same answer twice.
- Speech masking may have been good to know about as well!
- Anna is awesome!!

Extra comments on the Likert scale statements

The session was well organised.

- Very clear. Good pace
- Started on time
- Had a clear structure
- What was to be done was explained in the beginning and done well
- More time for the questions would have been good

The tutor was able to communicate ideas and information clearly

- Overview of topic, then purpose of topic, followed by procedure is the structure of how it was explained which was good! = better understanding

My ability to confidently recognise situations that need to be masked improved after the session

- Explanation was clear and the reasoning behind methods was explained
- Slightly. I don't feel confident in anything Alison taught
- I think if I was completely fresh, this would make a big difference

I think the session was useful for learning about cross-hearing

- Shadow effect demonstrated very clearly

L.2. Session 2 transcript of questionnaire feedback

I think the session was useful for learning about the plateau

- Have a better understanding of why we need the plateau
- Didn't understand it before today!
- Plateau plot is very visual (useful?)

I found maskME easy to use

The slider was sometimes challenging changing from laptop track pad to mouse! But

otherwise good!

- I found the graphics/audiograms a good visual. It was pretty frustrating manipulating sound levels on the bars. Handy to be able to use the keyboard. Made it slow!
- The slider controls made it easy to accidentally go one step too far etc.
- Sometimes layout and procedure was not that intuitive but okay after some coaching
- Keys to change level would be good

I would recommend the session as a tool for first-year audiology students

- Good consolidation of what we had already learned but I think that it would have been a good intro – the pace and layout made it easy to follow

L.3. Session 3 transcript of questionnaire feedback

List any positive aspects from today

- Clear structure to study efficiently
- Easy to follow
- Repetition of main points helps to remember them
- maskME was very easy/simple to understand and use
- Good communication
- Comprehensive information about audiology

What would you like to see changed in the session?

- Possibly provide some more explanation for technical terms
- More focused on PowerPoint than workbook for theory, I find that more easy to follow
- Actually doing the experiment with headphones would be more informative in a sense that it would be an immersive experience and therefore more memorable in the head.

Anything else you think we should know about the session?

- A lot of information at once maybe better split in 2 sessions
- No

Extra comments on the Likert scale statements

The session was well organised

- Lecturer's maskME didn't work properly – had to show on other PC, but still OK for small group

My ability to confidently recognise situations that need to be masked improved after the session

- I think I understand the general concept, but not really the functioning

I think the session was useful for learning about cross-hearing

- Have never really thought about that before, really interesting

I think the session was useful for learning about the occlusion effect

- I understand the concept, but at that point had already too much information to understand its impacts

L.3. Session 3 transcript of questionnaire feedback

I think the session was useful for learning about the plateau

- Would have to revise this at home to understand

I would recommend the session as a tool for first-year audiology students

- If they have the possibility to regularly use it to practice, yes

L.4. Session 4 transcript of questionnaire feedback from Groups 4 and 5 (audiology students)

List any positive aspects from today

- It was good to go through another way of learning masking. It helped solidify my knowledge around masking
- A really good review on cross hearing
- Kahoots was fun
- Everything explained well
- Explanations
- PowerPoints
- Kahoot fun
- Clear concise explanations from instructor
- Anna's clear delivery and instructions
- Workbook was excellent and would be very helpful
- Loved the Kahoot quiz! Heaps of fun
- Pace
- Use of visuals and demos to support verbal info
- Anna's ability to be relatable and teach us concepts
- PowerPoint use made it easier to understand
- Game idea was great, innovative (Kahoot)
- Shorter quiz was easier to finish on time
- The slides were really good, information was well explained and organised
- The time allotted for the tasks was good
- Anna presented well
- Kahoots
- Well presented
- Lots of breaks

What would you like to see changed in the session?

- The program confused me a lot
- I found the masking/tone sliders very clumsy to use
- The different coloured lines need defining on the software front page a lot better
- Maybe check if the cases are all uploaded
- Software layout so that it's easier to visualise
- Snacks
- Longer break
- Planned on a day when the café is open
- Technology

L.4. Session 4 transcript of questionnaire feedback from Groups 4 and 5 (audiology students)

- The slider changed to arrow keys
- Move through concepts slower slightly
- Improved software
- maskME takes a bit of time to fully understand
- Snacks please
- Technology
- All good, nice work!

Anything else you think we should know about the session?

- Not having to manually clear each session on the plateau graph when the case is changed
- Really good
- Snacks would have been great

Extra comments on the Likert scale statements

The session was well organised

- Only thing was that the software was not properly loaded onto the computer □
- Great pace
- Use of breaks and Kahoot quizzes throughout helped give good structure
- PowerPoint and games made it easy to follow and understand. Greater than previous session
- Nice one Anna, well communicated

The tutor was able to communicate ideas and information clearly

- Great explanations!
- Anna spoke in a clear and friendly way to help our understanding
- Information presented clearly with visuals to support
- Nice one Anna, well communicated

My ability to confidently recognise situations that need to be masked improved after the session

- I think being an aud(iology) student meant that it is harder to learn this way. It’s different to what we’re used to, so it’s confusing

I think the session was useful for learning about cross-hearing

- More so if we didn’t already understand it in other ways

L.4. Session 4 transcript of questionnaire feedback from Groups 4 and 5 (audiology students)

- The PowerPoint was very useful and clear but the software is confusing and makes it harder to visualise because you focus on the sliders and don’t need to look at the audiogram
- maskME software helped to visualise cross-hearing

I think the session was useful for learning about the plateau

- Graph (plateau plotter in maskME) is good. Would be even better if changing levels was displayed on audiogram rather than on sliders.

I found maskME easy to use

- Suggest adjustment arrows for intensity (yr1)
- Hard to manipulate levels you present tones/masking (y1)
- For people who are used to audiogram direct (? Can’t read), it would be much easier to use something similar
- Not use friendly, would be easier to use arrows on keyboard rather than mouse
- Was confusing at times – almost find audiometers themselves easier
- The software itself is outdated and clunky to use. Clear instructions were given with demonstration
- Software is not user friendly at all both in function and aesthetics. Need to be able to use keyboard to increase/decrease sound needs to look more modern to be more acceptable to students
- (“agree” was easy to use) when explained by Anna, and when practised
- Sliders, messy audiogram (hard to read)

I would recommend the session as a tool for first-year audiology students

- The PowerPoints and explanations, yes
- It’s quite messy to look at, can be confusing (maskME)
- If the software appearance and usability was improved
- Could be useful but could also be more confusing
- If changes to software use/look are made

If you attended the first session, to what extent do you think the masking session helped you

with masked audiograms done since?

- I think we had done too many already for it to make that much of a difference
- Good reminder of masking AC taking BC into account
- Helped with theory/limitations of concepts but not practical steps of actually doing masking

L.5. Session 4 transcript of questionnaire feedback from Group 6 (novice participants)

List any positive aspects from today

- Learned about masking, maskME tool
- Well organised
- Clear presentation and flow of ideas
- Kahoots was interesting
- I enjoyed it, I had no prior knowledge so was a great opportunity to learn something new
- The cash money
- I enjoyed the Kahoots and felt they aided in my memory
- Got to know how to assess my hearing loss
- Tutor is a happy positive person
- Thank you
- Happy session
- Breaks were useful, hence less tiring
- Learnt lots
- Competitive, unmarked class quiz was very fun and helpful for revising concepts (Kahoots)
- Interactiveness of the session, Kahoot quizzes were good to consolidate what was learned through workbook
- Well-organised and laid out
- I got up earlier
- I met with others
- I participated in this session
- Loved Anna's energy
- Talked in an easy-to-understand way
- Well structured
- The workshop was well structured to communicate ideas and there was clear instructions that related well to do the exercises
- I could learn more about hearing ability and physiology of the ear and hearing system

What would you like to see changed in the session?

- All good
- More memes
- Punctuality of the volunteers
- It would be more easy if (there) are yet more details regarding how to handle the software
- Less quiz
- More person-to-person help when using maskME
- More examples and picture guides for showing how to use maskME
- Split to multiple shorter sessions

L.5. Session 4 transcript of questionnaire feedback from Group 6 (novice participants)

- Coffee needed
- A demonstration before a new activity is introduced
- Having some refreshments like coffee of tea in the breaking time

Anything else you think we should know about the session?

- Wow, audiology is really complicated. Brain = melted ☺

Extra comments on the Likert scale statements

My ability to confidently recognise situations that need to be masked improved after the session

- I wasn't sure about how to plot shadow curves without any other information. I knew that they would match the bone conduction curve but not how to compensate for 40dB or 60dB attenuation for headphones or where the starting point is for a dead ear

I found maskME easy to use

- Needs to move with the keyboard arrows